Animal Subsistence of the Yangshao Period in the Wei River Valley:

A Case-Study from the Site of Wayaogou in Shaanxi Province, China

Hua Wang

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DECLARATION

I, Hua Wang, confirm that the work presented in this thesis is my own.

Where information has been derived from other sources, I confirm that

this has been indicated in the thesis.

ABSTRACT

This thesis focuses on the subsistence economy of the Yangshao period in the Wei River Valley, how it changes through time and how it relates to environmental change and changing social complexity. The research is based on faunal analysis at the Wayaogou site (6,500-6,000 BP) in Shaanxi Province, China. Pig and sika deer remains are studied in detail since they dominate the faunal assemblage. For the pig, its domesticated status is documented and its husbandry strategies are explored in detail; for sika deer, human hunting practices are investigated. Based on this, the subsistence system, especially the balance between pig husbandry and sika deer hunting practices, is addressed. Meanwhile, the utilization patterns of animal bones are investigated using contextual analysis, to understand human refuse discard behaviour and residential strategies.

Standard zooarchaeological methods and approaches are used in this study. For pig, size change, cull patterns, body part representation, and archaeological evidence is used to infer its domesticated status, husbandry regime and utilization. This study is enhanced by Linear Enamel Hypoplasia (LEH) analysis, which is applied to pigs from Wayaogou and other Neolithic sites in the Wei River valley, to explore further the environmental conditions and husbandry practices. For sika deer, the age structure, size change, body part representation and bone modifications provide information on human hunting strategies and selection, as well as other uses of the animal, such as for bone tools. Spatial analysis is undertaken to investigate the spatial distribution patterns of faunal remains from Wayaogou. Some special depositions and contexts are assessed to infer social meanings and implications of faunal remains.

The animal subsistence study is put into a broader context in an attempt to understand the interactions between climate fluctuations, human responses, subsistence strategies and social development and decline throughout the Neolithic in this region.

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INTRODUCTION

Animal domestication, and the position of animals within Neolithic subsistence systems, is one of the most enduring themes of interest for zooarchaeologists worldwide. However, it is a relatively new research field in China and issues related to economic subsistence have seldom been explored, since previous archaeological work mainly focused on establishing the Neolithic chronology of different regions, and the origins and developments of Neolithic communities and interactions between them. With the introduction of the new research theories and methods from the West since the 1980s, especially the wide appreciation of the research themes of the "new archaeology" and archaeological science, some interesting issues within the prehistory of China, such as the emergence of agriculture and economic subsistence in the Neolithic, has attracted more and more attention and energy in China. These new interests have also influenced archaeological research themes and methods, and even techniques of archaeological excavation in the field in recent years. Animal domestication and subsistence studies, along with plant domestication, have now become integrated parts of the research theme in Chinese prehistory.

Although it has been proposed that a few sites in China witnessed early pig domestication (Yuan and Flad 2002), systematic studies of pig domestication from one site or region have not been undertaken. This relates to the fact that scientific studies of faunal remains from specific single sites or regions have not been the focus of zooarchaeological research at present. The Wei River valley, which is located in the upper reaches of the Yellow River, represents one of the most frequently discussed centres for the emergence of agriculture in China. The Yangshao communities (the middle Neolithic) represent the most flourishing agricultural

societies in this region. The Dadiwan site in the upper Wei River valley has been proposed as the earliest agricultural occupation in this region (Bettinger *et al.* 2007, 2010) and large numbers of sites dating to the Yangshao period have been excavated, with good recovery of rich faunal remains. However, the domestication process of the pig in the Wei River valley has remained cloudy, and the subsistence strategies and human ecological behaviours of Yangshao period communities have not been well understood.

The research presented in this thesis mainly focuses on the animal subsistence economy of the Yangshao period in the Wei River valley, how it changed through time, and how it related to the local and regional environment. The research is based on zooarchaeological analysis of remains from the site of Wayaogou in Tongchuan County, Shaanxi Province, China. Data from published reports from other sites in the region will also be used for comparative studies in order to explore how subsistence changed through time. There will also be an attempt to discuss the motivation behind the temporal changes observed. Research focuses particularly on the analysis of pig and sika deer remains at Wayaogou since these two taxa dominate the animal assemblage. For pig, its domesticated status is assessed and documented, and husbandry strategies are explored in detail by the systematic analysis of pig skeletal and dental remains; for sika deer, hunting practices are investigated intensively through thorough analysis of their remains. Other minor taxa are also explored and discussed, particularly in relation to ecological reconstruction and the landscape niches they represent. Based on this, the subsistence system, especially the balance between pig husbandry and sika deer hunting, and the factors underlying this, will be explored from both cultural and ecological perspectives. Furthermore, the subsistence study will be put into a broader context, in an attempt to investigate the

interaction between climate fluctuation, human response, subsistence strategies and social development throughout the Neolithic in this region.

This thesis therefore aims to understand the animal subsistence patterns of the Wei River valley through the systematic study of faunal remains from the site of Wayaogou, and comparison with published data from other sites in the same region. The methods and approaches that have been frequently used to address such subsistence issues in the Western World (see below) will be introduced and justified, and applied to the material used in this study. This study also includes an ecological perspective for understanding human behaviour in the Neolithic. I also interpret the animal subsistence patterns in broader context, trying to understand the interaction between environment change and human adaptation. This may provide another perspective for approaching subsistence studies in China.

The following methods and approaches are adopted in this thesis.

First, there is a broad review of zooarchaeological studies in China. A critical review is given of the claimed patterns of animal utilization, especially domestication and linked questions of animal husbandry in China.

Second, standard zooarchaeological methods are applied to faunal remains from the principal site, Wayaogou, including species representation, age assessment, body part analysis and metrical analyses. With this analysis, various lines of evidence will be used to address the question of pig domestication and husbandry strategies, including morphometric changes, cull patterns and associated cultural remains. The York System for Zooarchaeology (Access based) is used as the recording database, which has been adapted for my sites and area.

Third, Linear Enamel Hypoplasia (LEH) analysis is applied to pig teeth from Wayaogou and three other archaeological sites in the Wei River valley, to enhance understanding of the status of pig at the site and provide more detailed information on environmental conditions and pig husbandry practices.

Fourth, contextual analysis is undertaken to analyze the spatial distribution of animal bone remains at Wayaogou, to explore refuse discard behaviour and residential strategies *in situ*. Taphonomic analysis is carried out in order to understand the deposition variations of assemblages recovered from different contexts. Furthermore, some special depositions and contexts will be assessed to infer social meanings and implications, in order to throw light on specific questions, such as social organization.

Fifth, the site of Wayaogou is compared with other Neolithic sites in the Wei River valley, to investigate subsistence strategy differences between them, how they change through time, and furthermore, to explore the interaction of climate and environmental fluctuation, subsistence change and social complexity processes.

The thesis is divided into the following chapters:

Chapter 1 is a critical review of Chinese zooarchaeological research themes and methods, which raises and reviews the research questions to be addressed in this thesis. Present methods used to document the domesticated status of animals in China will also be reviewed and the hypothesis for the domestication of different livestock in China will be assessed, which provides a baseline for the current study.

Chapter 2 gives a general introduction to the environmental background and

archaeological sequence of the study area. The modern and paleoenvironmental conditions are described and reviewed, and the environmental fluctuations throughout the Neolithic will be highlighted, which provides a broader environmental context for subsistence in the Neolithic. Finally, in this chapter, the archaeological excavations and findings at Wayaogou will be described in detail.

Chapter 3 defines the procedures and methods of faunal analysis in the thesis. Standard zooarchaeological methods are employed in this study, with the York system used to database the faunal remains at the site. The method of linear enamel hypoplasia is also given in this chapter.

Chapter 4 is the first of the results chapters, and presents the range and relative importance of taxa from Wayaogou, and furthermore an ecological diversity analysis based on the taxonomic representation is discussed in detail. In addition, the published faunal remains from other site in region are used here to trace the species spectrum change from the early Neolithic to the late Neolithic in this region, which hints at the domestication process of the pig and subsistence change.

Chapter 5 presents various lines of evidence used to document the process of pig domestication through analysis of the pig remains from Wayaogou, and issues concerning pig husbandry strategies will be discussed in this chapter. Published data from other sites in this region will be drawn on for comparison. Evidence from Linear enamel hypoplasia (LEH) will be used to enhance understanding of the status of pig at the site and throw light on pig husbandry strategies at Wayaogou.

Chapter 6 investigates the hunting strategies of sika deer. The morphology of sika

deer from Wayaogou are compared to these from Quanhucun, a late Yangshao site in this region, and the size variations are used to investigate environment fluctuations and the influence of hunting and farming intensification. Other issues concerning sika deer hunting practices are also explored in this chapter, such as seasonality and whether conservation or the reproduction of the species was considered by humans.

Contextual analysis of faunal remains is undertaken in Chapter 7 and the taphonomic variations between different groups of archaeological contexts are assessed. The distribution patterns and contextual associations of different types of archaeological features are used to hint at the social organization of the site, and a ditch outside of the features is interpreted as a ritual locale; the symbolic meaning of the ditch is discussed.

In Chapter 8, I draw together the various results of faunal analysis from the previous chapters, and discuss human husbandry and hunting practices in detail. Furthermore, the motivation of human hunting and herding behaviours are discussed from an ecological perspective, trying to understand how the behaviour of the animal species, especially the pig and sika deer, affect human herding and hunting practices. The pig husbandry and subsistence strategies are put in a broader context, trying to understand how these changes related to other factors, such as the environmental changes and social complexity in this region.

CHAPTER 1

A REVIEW OF ZOOARCHAEOLOGY AND ANIMAL DOMESTICATION IN CHINA

Zooarchaeological study is a relatively new discipline in China. Although faunal analysis was undertaken for the first time in the 1930s for the site of Anyang (Yinxu), which represents the archaeological remains of the capital of the Shang Dynasty (Taihard de Chardin and Yong 1936: 56), the animal bones from archaeological sites more broadly have not attracted the attention of archaeologists for a long time in China. Zooarchaeological research has been highly influenced by paleontological studies in term of research themes and methods. With the introduction of research theories and approaches from the West, archaeologists have increasingly begun to realize the importance of faunal remains from ancient sites, and the most important issue for zooarchaeological study: the interaction between humans and animals. Animal domestication has been the most frequently discussed topic for zooarchaeological study in China. Research has mainly focused so far on the questions when, where and how the livestock have been domesticated in China. Although some fascinating results have emerged, some problems still exist.

In this chapter, a critical review of zooarchaeological study in China will be given, mainly considering research themes and methods. The approaches and methods that have been widely used to document animal domestication in the West will be discussed and justified; this helps to understand the achievement and drawbacks of present research on animal domestication in China.

1.1 Critical review of methods and approaches of zooarchaeological research in China

Animal bones recovered from archaeological sites have been neglected for a long time in China, just as happened everywhere during the early stage of archaeological work in the 19th century. This is mostly related to the research themes of the early stage of Chinese archaeology: since the birth of modern Chinese archaeology in the early twentieth century, the reconstruction of national history has been considered to be the primary objective of this discipline. The establishment of a time-space framework and culture sequence is the major aim of archaeology within this paradigm. The study of archaeology in China has a close relationship with history, and one of the main purposes of excavation and analysis is to support the recordings in historic documents. This is different from the archaeological work in many parts of the world. Within this theme, archaeologists and researchers paid much less attention to faunal remains and other archaeological remains, such as plants, in their field work, let alone laboratory analysis and final interpretation, because faunas and plants, compared with ceramic assemblages, in general, were not regarded helpful in contributing to building the framework of culture sequences. Excavations often placed more emphasis on human remains, lithic and ceramic artifacts, and faunal remains were ignored during the excavation and discarded at the archaeological sites (Ma 2005).

Animal bones were characterized as natural relics and their presence at the archaeological sites were seldom considered to be related to human activities. The most important research question of zooarchaeology—the interaction between humans and animals in the past was not well appreciated by archaeologists in China.

During the 1970s and 1980s, archaeologists began to realize the importance of faunal remains and began to make a more careful inventory and analysis of faunal assemblages. In recent years, some faunal remains collected at earlier excavations have been re-examined, but a sizable number of such finds were discarded after the initial listing in the site reports. Animals buried in conjunction with humans were more likely to be better recovered and documented than those found in architectural remains, ash pits or other trash middens. For example, at the Bronze Age site of Anyang (3,384-3,100 BP), which has been identified as the capital of the Shang Dynasty, large quantities of complete animal skeletons were recovered from tombs (Taihard de Chardin and Yong 1936: 56; Youg and Liu 1949; Yuan and Flad 2006). These animals were buried with special attention from humans, who seem to have been focusing on them, since they appeared to be sacrificial.

From the beginning of this century, archaeologists in China have increasingly realized the importance of the animal bone material recovered from sites and they are trying their best to collect all the bones from the sites. In recent years, more and more zooarchaeologists have emerged and many of them have been involved in the zooarchaeological work in China. Although the situation has been much improved in recent years, the faunal remains are still not given enough attention at present. Because most of the excavations in China result from rescue projects and as archaeologists are facing high pressure in terms of timing, the systematic collection of bones is still very difficult and sometimes impossible. Most faunal remains have been recovered from excavations without the participation of zooarchaeologists. Systematic sampling and wet or dry sieving methods were not applied at most archaeological sites. Most animal bones were hand-picked and selected arbitrarily, with a preference for large taxa and large elements; small mammals, fish and bird

remains have always been lost due to such poor recovery techniques.

An impressive characteristic of Chinese zooarchaeology is that it is highly influenced by the paleontology discipline in China, which started quite early in the 19th Century, and has made great contributions to global paleontological studies. The theories and methods for the paleontology studies were widely used in the early stage of the zooarchaeological studies, and even today. With this influence, most efforts of laboratory analysis in China have been focused on identifying each specimen to species, even to genus. As a result, only a list of species present at the site is given in most reports. Quantification of faunal remains is rarely reported systematically and the morphometric data are missing in most reports. Methods of identification, measurements and quantification varied between different researchers, and results from different sites were thus less comparable. Faunal analysis related to human behaviour, such as frequencies of taxa, skeletal representation, kill-off patterns, and butchery patterns were not in consideration. And other information, such as butchery and pathology of the animal bones, are missing in reports, which make further analysis and comparison impossible.

Interpretation of faunal remains has been rather limited in archaeological reports. Most of the reports were concerned with interpreting subsistence patterns by comparing the proportion of domestic animals to wild ones. For example, if the proportion of domestic animals was higher than that of wild ones, the subsistence pattern was considered as an agricultural one. If the proportion of wild animals outweighed that of the domestic ones, it would be interpreted that hunting was the important subsistence mode. It should be noted that these interpretations were usually based on speculation, rather on systematic analyses. Environmental

interpretations were commonly based on the known relationship of some attributes of an animal with one or more characteristics of the environment. In terms of the status of the animals, most reports just proposed that a certain animal was domesticated without any evidence, or with very little, often not conclusive, evidence.

As for the major issues for zooarchaeology, like the domestication of animals, some research has been undertaken by a few archaeologists, such as the projects on pig and horse conducted by Yuan and Flad (2002, 2006), which made great progress on animal domestication in China. But basic work and research still needs to be done, and systematic standards and ways of recognizing domestication of different species of animals in China need to be constructed. Of course, Western zooarchaeological theories and methods can be introduced to Chinese zooarchaeological research, but the differences and variations between the Western and Chinese animals need to be borne in mind all the time. How to apply these theories and methods to Chinese zooarchaeological studies is a major issue which needs to be resolved.

1.2 Theories and approaches for the identification of animal domestication

Domestication can be regarded as a relationship change between human and certain species, shifting from obtaining the products of the dead animals to maintaining the most important products of the living animals—its progeny. Just as with crop cultivation, animal domestication definitely had a profound influence on human society. Domestication is a process rather than a result, so how to trace the process from the faunal assemblages recovered from archaeological sites, what kinds of changes had happened during this process, and how to interpret them, are all the most important issues for zooarchaeologists. Various theories and approaches have

been developed and widely applied to document the process of animal domestication, including zoogeographic evidence, morphological changes, metrical changes, species spectrum change, cull patterns, pathological evidence and the use of cultural remains. Recently, stable isotopic analysis and dental microwear have been frequently used to identify the domestication of certain species from archaeological sites. However, limitations of these approaches were also frequently discussed by researchers. In this section, I will have a critical review on the application of these theories and approaches and the potential and problems of each approach will be highlighted.

1.2.1 Zoogeographic evidence

Zoogeographic evidence is the most reliable for the domestic status of an animal, when remains of an animal are found beyond the natural range of its wild progenitor. For certain domesticated animals, for example, sheep, its ancestor mouflon (*Ovis orientalis*), has a restricted geographic distribution in Anatolia, western and southwestern Persia, so the domestication of the species must have occurred there. Thus, sheep remains recovered from elsewhere must have come from the domesticated animals introduced by human beings (Martin 1999). The introduction of the sheep, goat and other animals to the island Cyprus is considered as one of the earliest known of such anthropogenic events. As remains of sheep and goat ancestors are absent from the Pleistocene deposits in Cyprus and cannot be considered as endemic, the presence of sheep and goats, as well as other pre-ceramic Cyprus species, such as pigs, were brought to the island by pre-ceramic Neolithic human (Croft 1991:63-79).

The zoogeographic approach is the most reliable evidence. If an animal is found in an area beyond its natural range, we can surely tell it is in a domestic status as it

definitely has been moved into this area by human and is also under human care. However, it can only be applied to species with restricted distribution geographically, not only at present, but also in the past. It can not be applied well to certain species, such as the pig, since the wild boar is widely distributed in Eurasia (Oliver *et al.* 1993), and domesticated populations in very few regions can be regarded as being brought by human beings. Another limitation of this line of evidence for domestication is that it provides no information about the earliest domestication events and the process of domestication.

Another fact we should bear in mind concerning the geographic distributions of a species lies in that, the presence of bones of the wild stock in faunal assemblages is the premier evidence of autochthonous domestication, but it does not necessarily indicate the animals were domesticated locally, since there is the possibility that local wild stock were being hunted at the same time that domestic animals were imported and kept from elsewhere (Meadow 1989).

1.2.2 Morphological change

Morphological change was once considered the most reliable indicator of a fossil animal's domestic status, and was applied widely in domestication studies by zooarchaeologists at one time (Uerpmann 1978). As modern domestic animals indeed show large morphological differences from their wild ancestors, there should be morphological change from an early stage of domestication. The most significant morphological change is that the domestic animal is always smaller than their progenitors (Uerpmann 1978; Meadow 1984, 1989). Meanwhile, other morphological change occurs during the process of the domestication, for example, the general body proportion, horn shape, coloring, hair and fleece; only some of

these characteristics are reflected in the skeleton.

Body size diminution is a quite universal phenomenon when mammals were under human control (Davis 1981). But the factors that cause the diminution is quite complicated and several arguments have been proposed by the archaeologists, first, early human populations prefer the smaller and probably more easily managed animals (Boessneck and von den Driesch 1978); second, the size diminution of domestic animal is due to the poorer nutrition (Widdowson and McCance 1975); thrid, the diminution in body size associated with domestication resulted from unconscious or indirect selection by humans and appeared as a natural by-product of induced environmental conditions created under domestication (Tchernov and Horwitz 1991: 54-75). As most important event in the history of human and animal relationship, the size change under domestication probably resulted from several factors rather than just one factor. As the domestication is not only a culture event in human history, but also a biological process, the unconscious selection definitely contributes much to the size diminution. As morphological change is a biological process, it takes time to become obvious enough to be detected by humans. Recent studies of goat suggested that archaeologically detectable morphological markers of some species, such as goat, occurred at least 1,000 years after the evolution of specialized hunting into herd management within the natural habitat (Zeder 2006; Zeder 2010). This finding reshaped our understanding of the interaction between genetic change and morphological change during the process of domestication.

Although the size change may not witness the first steps of animal domestication, it can be used as a line of evidence to document the process of human selection behaviour and the corresponding results under domestication. In the Near East, size

diminution has been used to prove the domesticated status of many species, such as sheep/goat, cattle and pig. In China, the size change, especially the tooth size diminution, is the most frequently utilized evidence to argue the domesticated status of pigs from archaeological sites.

Except for domestication, we should bear in mind that other factors could also affect body size, especially the latitude or climate-related changes (Davis 1981). So when we try to trace the process of domestication, we should exclude the influence of these factors first; the comparisons should be made between sites that have geographic proximity; the possibility of climate change affecting the body size change should be first excluded. Body size comparisons of a species that have never been domesticated could be undertaken to argue whether there was a climatic fluctuation during the millennia in qustion. However, the difficulty in distinguishing human-induced change from those resulting from other biological or environmental factors limits the utility of this marker for animal domestication (Zeder and Hesse 2000: 2254-2257). Furthermore, the uncertainty over the pace and causal connection between body size reduction and human control also makes the utility of this marker difficult. In the northern Fertile Crescent, the influences of environmental condition were excluded since there was no size change for gazelles from final PPNA to Early and Middle PPNB and the increase of relatively frequency of small-sized sheep has been used to document the process of sheep domestication in this region (Davis 1981).

Other morphological differences used to document the process of animal domestication include horn changes, for example, most modern domestic goats have helically twisted horns, while the wild goat *Capra aegagrus* has scimitar-shaped horns.

1.2.3 Species spectrum change

Since the size change can't always be detected in the early archaeological sites due to the lack of faunal samples, species spectrum change is another method used to identify the advent of domestication, dependent upon recognizing the shift in the frequencies of different species. The shift from the earlier spectrum, which has high a proportion of species that have never been domesticated, to a later spectrum, which includes 'pro-domesticates' such as the sheep, goats, cattle and pigs, should reflect an economic shift from hunting to domestication. As for the geographic variation of animal species, the study of species spectrum should be restricted to a limited area.

This method has been utilized well to document the process of animal domestication in the Near East, with the most striking archaeofaunal changes of the species frequencies occurring between the Natufian and PPNB (Davis 1982; Legge and Rowley-Conwy 2000). From the earliest sites of the Near East, 11,000 years ago, a wide variety of wild mammals, as well as fish, molluscs, birds and plants, were exploited by human beings. The mammals included wild cattle, wild boar, gazelle, deer, fox and rodent. Later in the Neolithic, around 9,000 years ago and still before the invention of pottery, there was a great change in the proportion of the animal species found at the archaeological sites in Western Asia: remains of goat and sheep outnumbered those of all other animals. The transition from the wild species dominated assemblages, such as gazelle and fallow deer, to the domesticated species dominated assemblages, such as sheep/goat, clearly document the process of animal domestication in this region (Martin 1999).

Though an obvious change in species spectrum can be a sign of domestication of certain species, it is dangerous to use it to document domestication without additional evidence such as morphological change or cull pattern, because it is difficult to tell whether an increase in the later domestic species was due to the adoption of herd

management or the intensification of hunting strategies. Moreover, as the domestic species initially contributed a small portion to the subsistence economies, the species spectrum change probably can not tell the initial story of animal domestication. Another problem of species spectrum change lies in the environmental change which can also influence the species spectrum in an area. So we should first exclude the possibility of impacts resulted from environmental changes when we use this marker for domestication.

1.2.4 Cull patterns

Changes in age and sex profiles have been proposed as another evidence to document animal domestication. It is based on the assumption that the age and sex ratio of the domesticated herds is different from that found normally in the wild populations of a taxon (Zeder and Hesse 2000, Zeder 2001; Helmer *et al.* 2005). Domestic herds always have a high proportion of young adults, and also have a preference of females, which results from the controlled breeding and selective harvesting by humans, while human hunting always shows a variety of culling patterns, since the age and sex ratio of a wild species may vary in different seasons. Thus, the cull pattern produced by human hunting can not be the same as a domestic flock from a year round occupied site.

The utilization of cull pattern for domestication has also been widely challenged. The variety of population structures of wild ungulate herds has been demonstrated (Collier and White 1976) and there is no universal or standard cull pattern for hunting. As different hunting people may have different prey strategies, and as different human societies may utilize their domestic animals in very different ways, resulting in very different kill-off patterns, we should be careful when we try to interpret the age and sex structure as evidence for animal domestication. The

problem lies in that it is difficult to distinguish between various selective hunting strategies and those that reflect deliberate herd management and domestication. Another problem is that there are other factors which have influence on cull pattern such as disease, adverse climatic conditions, lack of food, predation. Hence, the high proportion of immature animals from archaeological sites cannott be the definitive evidence for domestication, and it should not be interpreted only as evidence for domestication. Another key obstacle in practice is that it is difficult to construct the separate male and female age profile which is necessary to detect the distinctive sex-specific harvest patterns of managed herds.

1.2.5 Evidence from stable isotope and dental microwear

Domesticated animals may have different diet from their wild ancestors, with human's supervision and feeding strategies. Stable isotope analysis has been frequently used to evaluate human and animal diet and foddering practices in recent years (Richard *et al.* 2003, Barton *et al.* 2009). By analyzing carbon isotope ratios and nitrogen isotope ratios in human and animal bones and teeth, their consumption patterns can be evaluated. A case study of stable isotope analysis of human and animal bones and teeth from a few Neolithic sites (Jiangzhai, Shijia, Xipo, and Kangjia, spanning the time period from 7,000 to 4,000 years ago) in northern China suggests that the diets of both human and animals (dog and pig) have high C13 values, and probably humans and these animals were highly reliant on the millet agriculture, whereas some wild species, such as cervids and bovids, have a predominantly C3 plant based diet (Pechenkina *et al.* 2005). This indicates that probably dogs and pigs at the site were controlled and feed by humans, and the connection between these species and humans support hypotheses that the animals were domesticated at the site.

Different diets may leave different microwear patterns on animal teeth. Recently, dental microwear analysis has emerged as an invaluable tool for the reconstruction of ancient diet (Teaford 1994; Wilkie *et al.* 2007). For example, studies by Ward and Mainland (1999) on modern pigs reveal significant differences in microwear patterns between stall-fed and free-ranging, rooting individuals. Stall-fed pigs are readily distinguished from rooting/free range pigs by the greater density of microwear features evident in the latter on both buccal and occlusal surfaces. Since domesticated animals may have a different diet habitat from the wild ancestors, and different feeding strategies, studies on animal dental microwear may provide clues to trace the status of animals from archaeological sites.

1.2.6 Other Lines of Evidence for Domestication

Other lines of evidence used to document domestication include bone microstructure, pathologies and other architectural and artifactual remains that reflect the new human and animal relationship.

DNA analyses are probably the most fascinating new methods to be applied to document the early domestication of animals. By examining the genetic linkage between the domestics and their wild forms, it has been widely used to investigate the origins and development of different species of domesticated animals all over the world (Loftus *et al.* 1994; Machugh *et al.* 2001; Fernandez *et al.* 2005; Larson *et al.* 2005). However, DNA studies suffer serious technical problems because of the easy contamination with modern DNA and the low rate of successful extractions (Fernandez *et al.* 2005). If these problems could be overcome successfully, DNA analysis is still a promising field to document the first step of animal domestication.

In the 1970s, researchers proposed that domestication causes changes in internal bone structure that could be used to mark domestication in sheep and goats, as well as in other species of domestic animals (Drew *et al.* 1971). It has been maintained that the bones of domestic animal show strong blue or yellow interference color on all articular surfaces when viewed through a crossed polarizer, while there was no such phenomenon on wild animal bones. It was really a pioneering piece of work and it represented the trend of archaeological science at the time. But unfortunately, subsequent attempts to use the blue-rim marker failed. Watson (1975: 375-383) argued that the blue-rim phenomenon were actually resulted from the post-depositional diagenesis, rather than from domestication. Although the blue-rim marker failed, there are some reasons to believe that there are some bone microstructure differences between the domestic animals and the wild animals (Zeder 1978: 69-86). The potential of this method demands that the cause of the differences should be explored and defined, which will make the marker a more valid case for domestication when the differences are detected and measured.

Pathologies are physical evidence of restraints or a shift in nutritional intake caused by human management. It can begin as early as the first or second generation. For example, pathologies in bone and jaws noted in sheep and goats have been interpreted as signs of human control of domestication at the site of Tepe Sarab in western Iran (Bökönyi 1977: 38) and Ain Ghazal in Jordan (Kohler-Rollefson 1989). For pigs, the linear enamel hypoplasia occurring on the molars has been frequently used to record the influence of domestication, and to trace the process of domestication from many Eurasian sites (Dobney *et al.* 2007).

Some other archaeological remains have also been interpreted as evidence for

domestication. For example, the impression of goat hooves made in the fresh mud-brick at the site of Ganj Dareh in highland Iran was considered as a sign of domestication (Hesse 1978: 314). A sheep figurine with a woolly fleece at the site of Sarab was interpreted as an early sign of the shift in pelage from the wild to the domestic form (Bökönyi 1977: 25). But these remains only indicate that those animals have a close relationship with humans, and we need other lines of evidence to argue for their domesticated status.

In general, morphological change and metric data, species spectrum changes and cull patterns are among the most common methods used to identify animal domestication from archaeological sites. However, we should bear in mind that each method has its own limitations; it is possible that the size of the animals and their age structures have been affected by environmental change, and changes in human hunting strategies. Species spectrum change requires a long chronological sequence from a single site or a series of sites in one region, and since it is based on recording the taxa range and frequency change through time, it can be misrepresented by intensification of hunting strategies. For cull patterns, it is difficult to determine whether certain patterns of age structure resulted from human husbandry strategies rather than hunting practice. Other methods, such as stable isotopic analysis and dental microwear, can be used to supplement the argument for animal domestication from archaeological sites. However, these two methods require special equipment.

As mentioned above, no single marker for animal domestication can provide unequivocal evidence when used alone, and arguments for animal domestication should based on multiple lines of evidence. Thus, if we want to document the domestication of some species convincingly, we should examine morphological

changes, cull patterns, species spectrum change, and other lines, all together if possible. This probably requires a large assemblage of animal bones from a single site covering significant spans of time or from a few sites within a limited region.

1.3 Research on the origins and development of Chinese livestock

Just like other areas in the world with a long history of civilization, the origins and early development of livestock is one of the most important issues for zooarchaeological study in China, and it has attracted many scholarly efforts inside and outside of the country. This section will give a broad review of studies on the origin and development of livestock, in terms of research themes and methods. Based on that, specific research interests and questions of this thesis will be defined.

Research on the origins and history of Chinese livestock has been closely related to studies on the emergence of Chinese civilization, as the domestication of animals and plants are considered to be one of the prerequisites for the rise of human civilizations (Diamond 2002). Before the 1950s, many scholars thought that Chinese civilization, characterized by black-on-red polychrome pottery and bronze vessels, diffused from western Asia; other characteristics of Chinese civilization, such as the domestication of animals and plants, the Chinese writing system and the chariot arrived late in China through cultural diffusion, either from western Asia or India (Bishop 1940). Meanwhile, some scholars argued that some characteristics of Chinese civilization were indigenous, such as oracle bones, silk worms and the decorative styles of the Shang Dynasty (Li 1954).

Since the 1950s, new archaeological finds from northern China have become numerous enough to suggest a distinctive civilization convention, which has been

used to strongly argue for indigenous Neolithic development in the Central Plain area of northern China. But the question of the domestication of pigs, cattle, sheep, dogs, chickens and possibly horses, along with cultivation of millet and rice, which have characterized the Chinese Neolithic culture traditions, have still remained a problem for archaeologists in terms of whether they were indigenous or adopted from elsewhere (Chang 1968). The process was more puzzling to archaeologists due to the lack of actual archaeological evidence. The site of Banpo in the Shaanxi Province, which was excavated in the 1950s, was regarded as witnessing the earliest farmers in north China, and researchers argued that pigs were domesticated from their wild ancestors in this region, and that dogs had been domesticated either for a long time before, or from a different species from another region because of their much smaller body size. Sheep, cattle and horses were proposed only as possible domesticates due to small sample size (Li and Han 1959). Watson (1974) proposed that two oblong foundations of buildings without fireplaces or other tokens of human occupation at Banpo were stalls for domesticated animals.

In the 1970s, with new archaeological discoveries, scholars gained the confidence to argue that agriculture was probably invented independently in China, but details of the process remain in question (Chang 1977). As for animal domestication, He (1977) made a reasonable conclusion based on limited archaeological data. He argued that the domesticated pig, which probably has multiple origins, was derived directly from local wild boar in northern China. Meanwhile, he proposed that most other common domesticated animals, such as cattle, buffalo, sheep, horses and dogs were also known to have existed in prehistoric China, but the goat, whose wild prototype was not native to northern China, must have been first domesticated in the Near East, then arrived this area around the second millennium BC. He concluded that domestic

animals always played a subordinate role in the subsistence system within the entire early Chinese system of field agriculture, which is quite different from that of the Near East, where animal domestication constitutes an equally vital part of agriculture as grain production (He 1977). Although He did not provide much information as to where Chinese domesticated livestock were first domesticated or by what processes, he did contribute an outline of the studies on the origin of Chinese agriculture and animal domestication. His proposal served as an important framework for further exploration into the development of a combined agriculture and herding system in China.

Since the 1980s, an increasing number of archaeological sites have been excavated and numerous animal bone assemblages have been recovered. When and where domesticated plants and animals first appeared in China has become a primary research question. Pigs, dogs, sheep, cattle, water buffalo and chickens have been the main focus for scholars trying to trace the domestication processes. In the following section, recent studies on the origins and development of livestock in China will be critically reviewed. The locations of the sites mentioned in the review are shown in Fig.1.1 and Fig. 1.2.

Pig

Pig domestication and early husbandry has attracted more scholarly effort than that of any other animals in Chinese archaeology, because of its important status in the subsistence system in China. Recent mitochondrial DNA studies of worldwide wild boar have revealed that there are at least seven centres of pig domestication in Eurasia, and China is an independent one (Larson *et al.* 2005). Recent research suggests that pig was first domesticated in China 10,000 ago (Yuan and Flad 2002).

Some scholars in China have argued that pigs were domesticated from local wild boar in different areas independently (Zhang 1979; Luo 2007).

The domesticated pig was first proposed for the Zengpiyan site (Fig. 1.1) in Guilin, Guangxi Province, dating to 10,000-7,000 BP in the 1970s, mainly based on age profiles showing that 65% of pigs were killed at approximately between one and two years old (Li and Han 1978), and some researchers believed that this was the earliest domesticated pig in China (Chang 1986; Nelson 1998). But other scholars doubted this argument (Yuan and Flad 2002), and they argued that the data of the Zengpiyan site are quite problematic, including the suspect radiocarbon dating and the context from which the pig bones were recovered. Also, the domestic status of pigs at Zengpiyan site was challenged by evidence that the average length of the lower third molar (M_3) was large and that pigs constituted less than 5% of the total mammals at the site (Yuan *et al.* 2008). However, the linear enamel hypoplasia (LEH) analysis of the specimens from Zengpiyan indicated that the index of this site was significantly higher than that for modern wild boar, but similar to other sites such as Jiahu site (Wuyang County, Henan Province), Yuchisi site (Anhui Province) and Huayuanzhuang site (Anyang, Henan Province), where domesticated pigs were proposed with more certain evidence (Dobney *et al.* 2007). Whether this result puts into the question the LEH method, or the wild status of boar at the site, is open to debate. However, from an ecological perspective, this is a natural resource-rich region where there is a wide range of wild animal and plant resources available for humans, and in this case, pig domestication may not have been a requirement for humans in the early Neolithic. In this case, it is perhaps more likely, that the Zengpiyan *Sus* are wild boar, especially since no futher evidence from southern China is forthcoming.

The Cishan site (Fig. 1.1), which dates to 8,400-7,400 BP, is another early Neolithic site where domesticated pigs are argued to be present. The case for the domesticated status of pigs initially seems much more convincing as it is mainly based on two criteria: first, age profile, with most pigs at Cishan being sub-adult (Zhou 1981); second, tooth measurement, with the average length of the pig M_3 being 41.4 mm (Yuan and Flad 2002), these measurements are similar to those of domesticated pigs, for which the average length is about 39 mm and the average width is 18 mm (Mayer *et al.* 1998: 39-53). But as the pig sample from Cishan is quite small and the tooth measurements do not fall properly into the range of domesticates, the argument that pigs at the site are domestic needs more work to be fully convincing; though it is possible that the Eurasian wild boar and feral swine that Mayer (*et al.* 1998) used may not be representative of tooth size range of pig populations in the early stages of domestication in China.

Fig. 1.1 The distribution of sites with evidence of early pig domestication

Another notable site, probably with early domesticated pig present, is Jiahu, Wuyang

County, Henan Province (Fig. 1.1), dating back to 8,700 BP. Recent systematic research on faunal remains from this site has been undertaken by Luo (2007), with the following evidence being used to argue for the domestication status of pig: first, the crowding of the dentition is quite pronounced in the pig jaws; second, most pigs at Jiahu died at one to two years old; third, pig bones make up a relatively higher proportion of faunal assemblage, compared to that of other sites. Another line of evidence is the phenomenon that some pig teeth were buried with humans in tombs. In addition, the LEH index value at the Jiahu site is higher than modern Chinese wild boar, indicating a domesticated status for pigs (Luo 2007). Recently, the domesticated status of pigs at the Jiahu site is supported by evidence from geometric morphometric approaches (Cucchi *et al.* 2011).

The Dadiwan site (Fig. 1.1) in the upper Wei River valley is the most western site with signs of early agriculture in northern China. It produced the earliest painted pottery and is a typical site of the "Laoguantai culture" ("Dadiwan culture") tradition, which extends from Dadiwan south to the Qingling Mountains and east down to the Wei River. The archaeological remains at Dadiwan cover about 3,000 years, from 7,800 to 4,800 BP and it can be divided into five phases: Phase 1 (pre-Yangshao), from 7,800-7,300 BP; and Phase 2 (early Yangshao), from 6,500-5,900 BP; Phase 3 (middle Yangshao), from 5,900-5,500 BP; Phase 4 (late Yangshao), from 5,500-4,900 BP; and Phase 5 (transition from Yangshao to Qijia), from 4,900-4,800 BP. Systematic analysis has been done on the faunal remains, and the domesticated status of pigs has been proposed based on two lines of evidence: first, the average length of M_3 is 37.06 mm; second, most pigs were killed between one and two years old (Qi *et al.* 2006). However, the research is quite problematic because M_3 measurements were reported without stratigraphic information, and morphometic changes from the

early phase to the late phase were not explored. With archaeological findings so far, the deposition at the Dadiwan site probably witnessed incipient animal and plant domestication in this region (Bettinger *et al.* 2007). Because of the long time sequence of archaeological deposition recovered from the site, scientific studies on faunal remains in the future would help us to understand the processes of animal and plant domestication in this region.

Archaeological finds from the Xinglonggou and Xinglongwa site in Chifeng city, Inner Mongolia (Fig. 1.1), are also frequently mentioned as evidence to argue the beginning of animal and plant domestication in northern China. The two sites are about 10 km away from each other and both of them dates back to about 8,200-7,000 BP (Inner Mongolian Team 1997: 1-26). Archaeological findings indicate that there is a cultural significance of *Sus* for the communities in this region because three groups of animal skulls were excavated from a house at Xinglonggou and two skeletons of pigs were buried with humans at Xinglongwa. However, morphologically, the pigs recovered from these sites belonged to wild boar as more than 65% of individuals had a third cheek tooth (M_3) longer than 40 mm; and this proportion increased with time (Yuan *et al.* 2008). Also, the age structure provided adverse evidence for the domestic status of these pigs. Based on archaeological finds at these two sites, researchers concluded either that pigs were already domesticated in the Inner Mongolian area at 8,200-7,000 BP, or that the wild boar were favoured for cultural reasons in this region.

The Kuahuqiao site, Zhejiang Province (Fig. 1.1), has been discussed as evidence for the presence of domesticated pigs in southern China. This region has been proposed as the origin of early rice domestication (Smith 1995; Bellwood 2005; Fuller and Qin

2010). It is dated to 8,200-7,000 BP and divided into three phases (Zhejiang Provincial Institute of Cultural Relic and Antiquity and Xiaoshan Museum 2004). The domesticated status of pigs was mainly based on evidence that the pig mandibles were significantly twisted and the teeth were disordered (compacted) due to a shortened lower jaw. Also there is gradual size reduction of the M_3 from the early to the late phases. The cull pattern indicated that the percentage of younger animals was increasing from the early to late phases (Yuan and Yang 2004). But one phenomenon that clashes with the process of pig domestication is worth noticing: the ratio of pig bones to all mammals decreases from the early to the late phases (Yuan and Yang 2004). The status of pigs in southern China seems more complicated because pigs make up a relatively lower proportion in the assemblages and the wild animal resources were abundant and intensively exploited throughout the Neolithic. Also, it seems there are size variations for pigs between north and south China (Luo 2007). Thus, the domesticated status of the pig at Kuahuqiao needs more convincing evidence.

Although the pig is the most thoroughly studied species in China and research on pig domestication in China has made great progress in recent years, with increasing new data and published research results, there is still a long way to go. Many questions concerning pig domestication still remain and need exploring further. One of the most important issues is what is the situation of the earlier stages of pig domestication in different areas of China? New archaeological findings are required to trace the first steps of pig domestication in China.

The theories and approaches used to document pig domestication are still quite problematic and need to be improved. So far, much of the evidence for pig

domestication is based on one criterion of morphological change, especially the size change of M_3, and the morphometric standard for distinguishing wild and domestic is currently not clear. Another problem in the determination of animal domestication is the lack of species spectrum change through time. To use this criterion effectively, more data from a large quantity of sites of different time periods or a site with a long time sequence are essential. As for cull patterns, systematic research on large assemblages of pig mandibles from archaeological sites would help us to build up a more convincing chart. Other lines of evidence, like bone microstructure, mtDNA and pathology are likely to contribute to the study of pig domestication in China in the near future.

Dog

It is most likely that the Dog (*Canis lupus familiaris*) entered a symbiotic relationship with humans as early as 20,000 years ago in various places in Eurasia. A larger genetic variation in East Asia than in other regions, and patterns of phylogeographic variations, point to an East Asian origin for the domestic dog (Savolainen *et al.* 2002).

The dog was probably the first domesticated animal in China and it was first found among the hunter and gatherer communities at the end of the Pleistocene, as represented by the Nanzhuangtou site, Xushui County, Hebei Province (Fig. 1.2), dating to 10,500—9,700 BP (Li *et al.* 2000), which probably documented the earliest dog domestication of China (Olsen *et al.* 1980; Baoding Institute of Cultural Relic Management *et al*. 1992). Scholars found that the dentition length of dog mandibles at this site was 79.9 mm, shorter than the 90 mm of modern wolf specimens kept in the Institute of Paleozoology and Paleohumans of the Chinese Academy of Sciences

and, as the teeth had already undergone significant changes by this time, scholars argued that the history of dog keeping in China goes further back (Yuan *et al.* 2008). Dogs were widely distributed at Neolithic sites in China. Although in most cases they were not present in large quantities, they impacted upon the faunal remains of other animals present at the sites, as gnawing marks are commonly present on the bones from archaeological sites. Although dozens of sites have yielded domesticated canid remains, specific details about the canids are often scant and lacking in descriptions of morphological features. It would be interesting to investigate the development of different breeds of dogs during the Neolithic. Recent studies based on morphological analyses of dog remains show that different breeds of dogs developed in northwestern China as early as the middle Neolithic (Nobuo *et al.* 1998).

In the Wei River valley, domesticated dog remains have been found at sites of the early Neolithic, such Beishouling in Baoji County, Shaanxi Province (Fig. 1.2) (Zhou 1983). At the Banpo site, at least five skeletons of domesticated dogs have been recovered, identification being based on the curved inferior margin of the mandibles, small carnassials, protruding rostrum and small skull size (Li and Han 1959: 176). Many dog remains have been found in refuse areas, along with food debris, leading to the speculation that the dogs were also used for consumption (Clutton-Brock 1981). However, this argument needs further analysis of butchery marks to make it more convincing.

Cattle

The origin of domesticated cattle (*Bos taurus*) in China remains problematic because they are rarely encountered at the early and middle Neolithic sites, although the wild prototype of cattle has existed in prehistoric China (He 1977). From the late

Neolithic, the Longshan period, they were present in considerable numbers at archaeological sites in both northern and southern China.

Mitochondrial DNA sequence data for cattle suggest that there were two independent centres for cattle domestications in the world (Loftus *et al.* 1994). *Bos taurus* was first domesticated in West Asia and Europe, probably between 10,000 to 8,000 BP from its ancestor, *Bos primigenius*, which became extinct in the 17th century. *Bos indicus* (the Indian zebu) was believed to be domesticated first in Asia around 5,000 BP. Genetic evidence indicates that domesticated cattle in China can be divided into two groups: the northern ones and the southern ones. The northern Chinese cattle are very close to the cattle of European origin, *Bos taurus*, whereas the southern ones seems closer to the Indian zebu (Lei *et al* 2006). As *Bos primigenius* in China are present in Pleistocene sites, and as wild cattle of the species *Bos namadicus* (an ancestral form of *Bos indicus*) had already reached China and Siberia in the Holocene from their supposedly original habitat in India (Zeuner 1963: 203), it is possible that cattle were domesticated locally in China. However, cattle remains are always present in small quantities at the early and middle Neolithic sites, which make the studies of cattle domestication in China quite difficult. Hence, the date and the locations of the earliest cattle in China are not quite clear at present.

Cattle remains from the middle Neolithic sites in northern China were always categorized as possible domesticated animals because no convincing evidence could be provided due to small sample size (Li and Han 1959); others were proposed as domesticated animals mostly based on the size evidence (Zhou 1983; Qi 1988). The domestic status of cattle at these sites has been doubted by others (Huang 2003: 608). Other cattle remains were recovered from ca. 5,000 years old strata at Fulinbao and

at the Neolithic site of Anban (Fig. 1.2), but their status in regards to domestication needs more studies to be confirmed (Flad *et al.* 2007: 192). Some scholars suggested that the earliest domesticated cattle appeared in China in the late Neolithic because cattle were present in small quantities at middle and early Neolithic sites, while they became quite common at late Neolithic sites (Yuan 2001). A complete cattle skeleton has been uncovered at the Shaitaisi site, Henan Province (4,500-4,200 BP) (Fig. 1.2), which has been used as evidence to document the earliest domesticated cattle in the middle to lower reaches of the Yellow River (Yuan *et al.* 2008). But whether this finding represents the earliest domesticated cattle in China, and how to characterize the occasionally recovered cattle fragments from earlier Neolithic sites remains a question. Based on the evidence of morphmetric information, kill-off patterns, species spectrum change and culture remains, Lv proposed that the earliest cattle domestication occurred at the end of the late Neolithic (4,500-4,000 BP), and a few sites in the Yellow River valley were among the location for early cattle domestication, including Dahezhuang and Qinweijia (Gansu Province), Pingliangtai, Wadian, and Shantaisi (Henan Province) (Fig. 1.2) (Lv 2007). However, the research could be challenged due to the small sample size.

An important question about cattle domestication asks for what purposes cattle were first domesticated in China. Some scholars argued that the primary or principal reason for cattle domestication was the exploitation of meat (Jia and Zhang 1989). Others proposed cattle may first have been domesticated for the exploitation of power, which could be used in cultivation and transportation in daily life (Qi 1988). Recently, Yuan *et al.* (2007) proposed that religious significance could be another motivation for cattle domestication, as cattle have been extensively used for sacrifice in the late Neolithic and early Bronze Age in China. However, this argument needs to

be supported by further evidence. In terms of the exploitation of cattle for transportation power, pathology studies are a potential tool to trace the evidence for the early stages of cattle exploitation.

Sheep/goat

Neither the sheep nor the goat seem to have been domesticated indigenously in China, as the wild bovids in this region, such as Argali (*Ovis ammon*), Mongolian gazelle (*Procapra gutturosa*), mainland serow (*Capricornis sumatraensis*), bharal (*Pseudois nayaur*) and common goral (*Nemorhaedus goral*), were not the progenitors of domesticated taxa (Flad *et al.* 2007). Phylogenetic analysis indicates the mtDNA of neither Argali (*Ovis ammon*) nor Urial (*Ovis vignei*) is closely related to domesticated sheep in China (Cai *et al.* 2007).

Archaeological data suggests that the sheep/goat were probably first domesticated in the Near East. Unlike many other domesticates, genetic evidence for goats suggests that they may have been domesticated only once (MacHugh and Bradley 2001). The goat was probably domesticated in the Zagros or surrounding areas, about 10, 000 years ago (Zeder and Hesse 2000).

In China, archaeological evidence for sheep precedes that for goats. Sheep were found in the Hexi Corridors by the beginning of the second millennium BC and domesticated sheep have been identified in strata of this period at the Dahezhuang site (Institute of Archaeology, CASS 1974), Qinweijia site (Institute of Archaeology, CASS 1975) and Donghuishan (Flad *et al.* 2007) (Fig. 1.2).

Scholars proposed that domesticated sheep and goats appeared around 4,400 BP

along the middle and lower reaches of the Yellow River (Yuan 2007), as they abruptly appeared in abundance at almost every site after this date. Flad *et al* (2007) proposed that domesticated sheep were introduced into northwest China, along with wheat, sometime between 4,000 and 5,000 BP, based on the archaeological findings in this region. Sheep remains have been identified occasionally at earlier sites in the Wei River valley. For example, the Banpo faunal assemblage contained sheep, dating to 6,900-5,800 BP (Li and Han 1959), although they were not necessarily domesticated animals. Likewise, the Lingkoucun Caprinae bones date to 7,500-5,500 BP, and the status of them is uncertain. Sheep bones were identified at the Longshan period site of Kangjia (Liu *et al.* 2001) (Fig. 1.2). Sheep from many other Longshan sites are frequent and more confidently thought to be domesticated individuals. In the upper Yellow River, the Zongri site of Xiangnangou (Fig. 1.2) likewise contained sheep bones from more than 4,000 years ago (An 2007), and these sheep are thought to be domesticated. Other sites in which sheep remains are identified as domesticates include Qugong and Zhukaigou (Fig. 1.2), both of which date to between 4,000-3,500 BP (Huang 1996: 400-421).

Actually, in China, sheep and goat remains have not been well distinguished at most sites. All of the earliest domesticated caprines in published reports are identified as sheep rather than goats, with the exception of Kangjia (Liu 2004: 49) which is said to contain goats. Also, the criteria used to distinguish between domesticated sheep/goat and other wild species present in China such as bharals, serows, gorals and argali, are not well established.

Considering domesticated sheep/goat in China, problems still remain, such as how the caprines had been introduced to China, and the introduction route is not clear to

us. The status of *Ovis* or *Capra* remains in early sites in China remains quite controversial; how to exactly characterize the early caprine remains in China is an important issue. Comparing the morphological differences between archaeological remains of Caprinea and the local wild species is necessary to trace their relationships.

Water buffalo

Mitochondrial DNA analysis of water buffalo indicates that it can be classified as two subspecies: river buffalo and swamp buffalo, and it has been proposed that swamp buffalo were domesticated independently in China whereas the river buffalo were domesticated in the India subcontinent (Kumar *et al.* 2007).

Since the domestication of water buffalo is closely related to rice cultivation in southeastern China, archaeologists proposed that the buffalo was indigenous in southern China and it has been domesticated since very early times (Zeuner 1963); the earliest domestication of water buffalo occurring in the rice growing region of southern China or indo-China, although there is no archaeological evidence to support this supposition (Clutton-Brock 1981: 141-142).

Osteological evidence indicates that wild buffalo existed in the Pleistocene of China, but whether these are ancestors to the domesticated races remains a question. The excavation in Anyang in the 1930s indicated that the buffalo makes up a large proportion of the entire osteological remains; two well-known Chinese scientists believed that the Chinese buffalo (*Bubalus mephistopheles*) was native to both southern and parts of northern China (Young and Liu 1949). Buffalo remains at the Hemudu site in Zhejiang Province were identified as domesticated animals and some

scholars proposed that modern water buffalo in China was first domesticated in the Yangtze River region during the Neolithic period around 7,000 years ago (Chang 1986: 211; Chen and Li 1989; Bellwood 2005: 125). The domestication of water buffalo probably followed the development of rice cultivation in the lower Yangtze region of China about 8,000 years ago and the spread of this agriculture system; with it, the swamp buffalo from the southern China to mainland Southeast Asia dates to about 5,000 years ago, and to Sumatra and Java about 3,000-4,000 years ago (Bellwood 1992). Some scholars challenged this premise and argued that water buffalo was first domesticated in South Asia based on morphological studies of ancient buffalo remains from South Asia (Patel 1997; Patel and Meadow 1998).

Water buffalo remains have also been identified at Neolithic sites in northern China. In the Wei River valley, some water buffalo remains have been found in a few sites. The Baijiacun site (Fig. 1.2), dating to 7,500-6,250 BP (Zhou 1994), and the "Longshan culture" site of Kangjia (4,500-4,000 BP) (Liu *et al.* 2001) (Fig. 1.2), both include bones identified as water buffalo, which seems to be morphologically domesticated. There remains a debate about the status of these buffalo remains as water buffalo occurs in small number at these sites, which makes systematic research very difficult.

The domesticated status Chinese buffalo *B. mephistopheles* has been challenged by Liu *et al.* (2004, 2006) based on the following evidence: first, there seemed to be no size change from the early Neolithic to Bronze Age; second, water buffalo was very rare after the Hemudu culture, which is not coincident with the argument that rice cultivation and plough agriculture had been developed during the late Neolithic in the lower Yangtze River (Qin *et al.* 2006). In addition, ancient DNA analysis has been undertaken which indicates that the indigenous water buffalo from Shaanxi

Province displays no direct connection with modern domesticated water buffalo, failing to support the assumption that water buffalo were first domesticated in China (Yang *et al.* 2008). But since all the samples collected for ancient DNA study are from northern China, it is too early to conclude that the domestication of water buffalo happened in other regions rather in China.

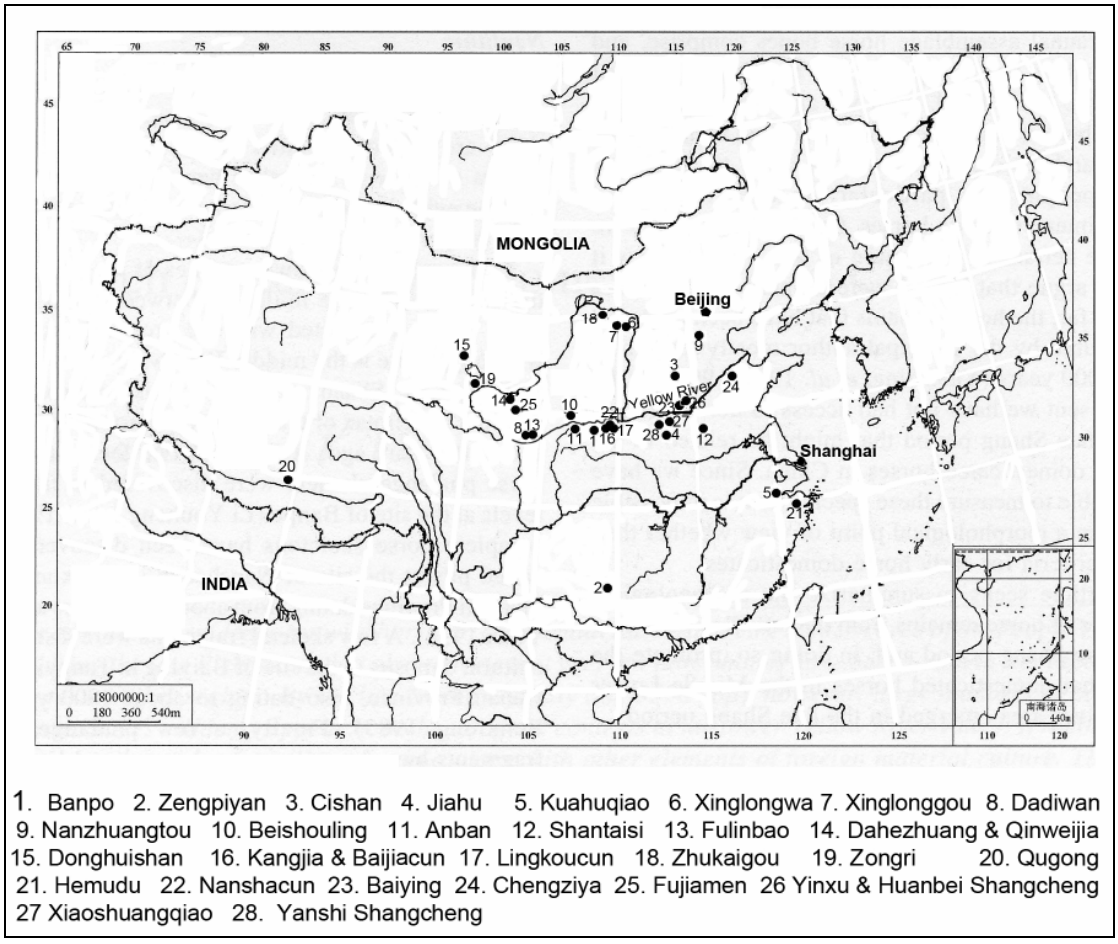


Fig. 1.2 The distribution of sites with evidence of early Chinese livestock (sites mentioned in this review)

There are a few problems with the Chinese buffalo research: first, water buffalo and cattle coexist in some parts of China today, which should also be the case in the past. The criteria to distinguish water buffalo from cattle are not yet quite clear and standardized, so all the buffalo studies should be based on the premise that all the

specimens are definitely water buffalo. Second, the reason why water buffalo has been domesticated needs to be investigated.

Chicken

Most scholars believe that the red junglefowl was the ancestor of the chicken (West and Zhou 1988). For a long time, it was agreed that chickens were first domesticated in the region of the Indus Valley around 4,000 BP, based on the evidence at Mohenjo-Daro (Carter 1971; Crawford 1984).

He (1977) argued that the southern part of China, like India, Burma and Southeast Asia, must have been one of the original homes of wild fowl. The domesticated chicken has been identified at middle Neolithic sites in northern China, such as Cishan, Hebei Province (Zhou 1981), Beishouling, Baoji County, Shaanxi Province (Zhou 1983), dating to 8,000 BP (Fig. 1.2). The domesticated status of these fowl is based on the size evidence, and morphological studies indicate that tarsometatarsal bones from Cishan range from 70-82 mm, longer than that of the red junglefowl (62-68 mm), indicates the domestic status of these birds (Zhou 1981).

Geographic distribution evidence has been used to argue for the domestic status of those chicken remains recovered from northern China (West and Zhou 1988). The modern distribution of the red junglefowl is in Southeast Asia, areas with a temperature of more than 50 °F. Paleoclimate and vegetation studies indicate that the distribution of wild junglefowl has changed very little during the past 10,000 years, so north China is not within the distribution area of junglefowl. So the finding of the chicken bones in northern China probably relates to domesticated individuals (West and Zhou 1988). Based on archaeological evidence for chicken domestication from

China, Asia and Europe, they proposed that chickens were first domesticated from the red junglefowl (*Gallus gallus*) in Southeast Asia before the eighth millennium BP and taken north to become established in China by 8,000 BP, possibly spreading to Europe via tribes of the Russian Steppe. Moreover, West and Zhou (1988) argued that domestication in India occurred much later, either independently or by diffusion from Southeast Asia. Yuan (2001) challenged this argument as the domestic status of chicken in northern China was only based on the measurement of the tarsometatarsal and he proposed that domesticated chickens were not present in the Neolithic of China.

Issues related to chicken domestication in China are not quite clear since the status of chickens at most Neolithic sites have not been well established. Geographic distributions and morphmetic information are the only two lines of evidence used to argue for the domesticated status of chicken in China. The problem with geographic evidence lies in the fact that, although the wild progenitor of chicken is absent in northern China, this need not have been the case in prehistory. In addition, criteria that distinguish the domesticated chicken and wild fowl species have not been well established. Thus, chicken domestication remains an important question for researchers and different lines of evidence need to be used to address the status of chickens from archaeological sites in the future.

Horse

The domesticated horse was the last of the five most common livestock animals to be present in China. Mitochondrial DNA analysis indicated that horses were domesticated from several wild populations, which individually had low genetic diversity (Jansen *et al*. 2002). Archaeological evidence indicates that domesticated

horses were distributed from Ukraine to Kazakhstan in the sixth millennium BP, which illustrates the probable timing and locations of incipient horse domestication (Olsen 2006).

During the late Pleistocene, wild horses were quite common on the open plains of Europe, Asia, and North America and they were exploited by human beings (Clutton-Brock 1981:80-90). There are 33 Late Pleistocene locations where horse fossils have been recovered in China, most of which are in the northern part of China (Yuan and Flad 2006) and almost certainly represented wild populations.

Horse bone fragments are encountered occasionally on the Neolithic sites of north China. In the upper reaches of the Yellow River, horse fragments have been recovered in the Fujiamen site (5,000 BP) (Yuan and Flad 2006), the Dahezhuang site (3,700 BP) (Institute of Archaeology, CASS 1974), the Qinweijia site (Institute of Archaeology, CASS 1975). In the middle and lower reaches of the Yellow River, horse remains have been found at the Banpo site, where two teeth and a single phalanx element were found in the cultural levels (Li and Han 1959). At Nanshacun in Huaxian County, Shaanxi Province, dating to 4,000 BP, two complete horse skeletons have been recovered in pits (Wang 1998). A few skeletal fragments were discovered in open living surface deposits at Baiying site in Tangyin County, Henan Province, dating to about 4,000 BP (Zhou 1983). In the lower Yellow River, a few phalange element fragments have been discovered in levels at the “Longshan culture” site of Chengziya (late Neolithic), Shandong Province, dating to 4,000 BP (Liang 1934).

Some scholars argued that any horse bone discovered on archaeological sites

indicates the presence of domesticated horses, regardless of what percentage of the total faunal assemblage horse bones comprise, so they argued that domesticated horses may be present in China as early as in the middle Neolithic Yangshao period (Olsen 1988). Zhou (1983) argued that the horse remains present at the late Neolithic site of Baiying in Henan Province were probably domesticated. But since these findings of Neolithic horse remains are quite occasional and also small in number, the status of the horse in this period remains controversial.

It has been suggested that horses became common domesticated animals in the late Shang Dynasty, as archaeological findings at Yinxu site indicated that horse-chariot pits and horse pits are quite numerous, which strongly suggests that horse at this site were domesticated (Yuan and Flad 2006). But archaeological finds indicated that horses were not used as sacrificial animals during the early and middle Shang phase, when animal sacrifice was quite common, and when domesticated pigs, cattle, water buffalo and sheep, as well as elk, were used for sacrifice. There are no finds of horse sacrifices at Yanshi Shangcheng in Henan Province (3,600-3,400 BP) (Shang Wall Team, Institute of Archaeology, CASS 2001), Xiaoshuangqiao, Zhengzhou City (3,435-3,410 BP) (Song *et al.* 1995), or Huanbei Shangcheng (3,370-3,220 BP) (Yuan *et al.* 2000). The abrupt increased presence of horses in the late Shang period indicates that domesticated horses in China diffused from the north or west, resulting from exchanges between agricultural peoples in the Yellow River valley and pastoral groups living to the north at that time (Yuan and Flad 2006).

1.4 Zooarchaeological research themes of the “Yangshao culture” in the Wei River valley

The first animal bone report of “Yangshao culture” in the Wei River valley was

published in the 1950s, based on the faunal remain studies at the Banpo site in Shaanxi Province (Li and Han 1959). Large numbers of the Yangshao sites in the Wei River valley have been excavated since the 1970s, and animal bones were recovered by poor recovery techniques without zooarchaeologists' participation. So neither systematic sampling nor wet or dry sieving methods have been applied at those sites. Meanwhile, large quantities of zooarchaeological reports of the Yangshao sites have been published, including Jiangzhai (Qi 1988), Xishanping (Zhou 1999), Shizhaocun (Zhou 1999), Lingkou (Zhang *et al.* 2003), Dadiwan (Qi, *et al.* 2006), Kangjia (Liu 2001), Baijiacun (Zhou 1994) and Quanhucun (Hu in preparation). Most of these reports are a small part of the whole excavation reports; they are fairly simple, and some of them are appear as appendices. Unfortunately, most of those studies on faunal remains are only biologically oriented, focusing on the identification of animal bones to species or genus level, whereas the economic subsistence of sites was seldom explored. An exception is Dadiwan (Qi, *et al.* 2006) in upper Wei River valley.

As mentioned above, the domestic status of pigs has been explored in different areas of China. The origin of pig domestication in the Wei River valley can be traced back to the early Neolithic (eg. studies at the Dadiwan site; see previous section). Unfortunately, we know very little about the beginning of pig domestication at this phase due to poor recovery technique and limited laboratory analysis, so new archaeological material and data, and systematic research is imperative to trace the first steps of animal domestication in this area. During the Yangshao period, pig husbandry clearly played a significant role in the subsistence economy, but management practices and husbandry strategies have seldom been investigated.

Just like other areas of China, research on the subsistence of the “Yangshao culture” in the Wei River valley was mainly based on the proportions between domestic and wild animals. The status of livestock was not thoroughly investigated in previous studies and the domestic status of the pig, the dog and sometimes the chicken was taken for granted, with either no or very little supporting evidence. The process of animal domestication or changes in the pattern of animal herding practice was not investigated. Morphometric data are seldom given in the faunal reports, and methods and criteria of measurements vary between researchers, which make comparisons difficult. Recent stable isotope analysis on pig and human bones at a few sites in the Wei River valley indicated that Neolithic farmers of the Yellow and Wei River were consuming millet, as well as pigs, and that there is a close connection between millet agriculture and pig husbandry (Pechenkina *et al*. 2005).

1.5 Key research interest and questions

My key research interest is the subsistence system of the middle Neolithic (Yangshao period) in the Wei River valley. Previous faunal reports suggested that pigs and sika deer played an important role in the subsistence (Qi 1988; Qi *et al*. 2006), which needs to be enhanced by the faunal remain studies from the site of Wayaogou. I am interested in the status of pig (domesticated or wild), pig husbandry regimes, and the relationship between pig husbandry regimes and social organization in prehistory. Deer hunting strategies is another aspect to aiding understanding of the subsistence system. Based on this, I expect to gain a whole picture of the subsistence of the Yangshao period.

From this main research aim, four specific research questions emerge:

1) Palaeoenvironmental reconstruction

Palaeoenvironmental reconstruction helps to understand human and animal behavior, by providing the ecological background for the subsistence economy and pig husbandry study. I will develop a broad view on the habitat and behaviour of these species present at the site, which will provide information for palaeoenvironment reconstruction. Also, by comparing sites of different periods, I will explore the species spectrum variations between sites.

2) Pig domestication and husbandry practice

Pig domesticated status of the Yangshao period has been proposed (Yuan and Flad 2002). With systematic faunal analysis from Wayaogou and other Neolithic sites in the Wei River valley, this proposition will be tested. Furthermore, the process of pig domestication in the Wei River valley will be explored. In addition, I am trying to gain a thorough picture of pig husbandry: what kind of husbandry strategies had been applied to pigs? Were they free-ranged or enclosed? Were domestic pig and wild boar coexisting in the same sites? Did crossbreeding between wild (or feral) boar and domestic pigs occur at the site? If it did not occur, why was that, and what kind of specific relationship between pigs and human beings does it imply? Was there any specific herding regime for pigs, such as penning or stalling and why? What is the relationship between pig domestication and plant cultivation at the site? Is there any special treatment of pig remains at the site?

A broad review of archaeological finds, such as plants remains, and penning and dung remains will be given, and data from other sites will be used since the

information of this type was missing at Wayaogou due to poor recovery techniques. Based on this, I will explore how the strategies of pig husbandry might have changed from the middle Neolithic ("the Yangshao culture") to the late Neolithic ("the Longshan culture") in the Wei River valley, and how it related to the environments and social complexity process.

3) Sika deer hunting strategy

Deer also played an important role in the animal subsistence economy during the Yangshao period. Some researchers even argued that sika deer had been domesticated during this period (Zhou 1983: 145-153; Qi 1988: 535), but this argument has little support now. Deer hunting practice provides useful information for understanding the subsistence economy and the relationship between the economy and environment during the Yangshao period. Unfortunately, very little research has been done on deer hunting practices. The research will mainly focus on deer hunting strategies at the site: whether the conservation and reproduction of the species was considered by the humans. In what season did the mass deer hunting occur and why? A review of the environment and behaviour of deer will be given and some ecological models generated from ethnographic studies will be used for the understanding of how and why sika deer were hunted during the Yangshao period. The traditions of the Yangshao communities will be defined and the ecological behaviour of the pig and sika deer will also be considered to explain this. The ecological balance between hunting, husbandry and cultivation will be discussed to shed light on why deer hunting continued in Neolithic China when pigs were domesticated.

4) Contextual analysis

I also intend to examine animal remains at the context level, and the influence of

different taphonomic factors on faunas will be assessed, trying to explore the taphonomic variations between different types of archaeological contexts. Contexts with different depositional histories of faunal remains may have experienced different taphonomic processes. And also, some contexts with special deposits will be assessed, trying to investigate the social meaning of animal remains recovered from these contexts. The distribution pattern of the faunal remains will also be used to explore humans' discard behaviour, to shed light further on the social organization of the Yangshao period.

CHAPTER 2

BACKGROUND TO THE STUDY AREA

2.1 Modern physiographic settings of the study area

The Wei River, lying in the north-central China, is one of the most prominent tributaries of the Yellow River. The Yellow River in northern China and the Yangtze River in the south stands out in the physiographic setting of China. Both of them originate in the Tibetan Plateau, and flow to the east, draining most of the vast eastern farmlands of China. These two rivers, along with their numerous tributaries, have played an important role in the origin of agriculture systems in China.

As the most prominent tributary of the Yellow River, the Wei River is about 800 km long, rising in the mountains of southeastern Gansu Province, flowing east through Shaanxi Province to join the Yellow River. The Qinling Mountains rise abruptly on its southern edge, many of them rising to as high as 3,000 metres above sea level, cutting the valley off from southern Shaanxi. The northern edge of the valley is marked by a series of calcareous mountains. An impressive aspect of the landscape is the widely and thickly distributed loess which contributes a part of the loess plateau of northern China (Fig. 2.1). The loess steppe extends uninterruptedly from the foot of the northern mountain system to the bank of the Wei River. The prominent tributaries of the Wei River include the Jing River, Ba River and Luo River in the north and some small rivers and streams in the south, originating from the Qinling Mountains.

Today this area is dominated by widespread and thickly distributed loess. There is

SE-NW gradient of modern climate in the Chinese Loess plateau, due to the interaction between the winter and summer monsoons. That means, not only annual temperature but also precipitation decrease gradually from southeast (10℃ and 600 mm) to northwest (7℃ and 350mm), whereas the aridity increases from the southeast to northwest. The vegetation closely follows the aridity trend: broadleaved deciduous forest in the southeast corner, forest-steppe in the southeastern part, steppe in the northwestern part, and desert-steppe in the northwestern corner.

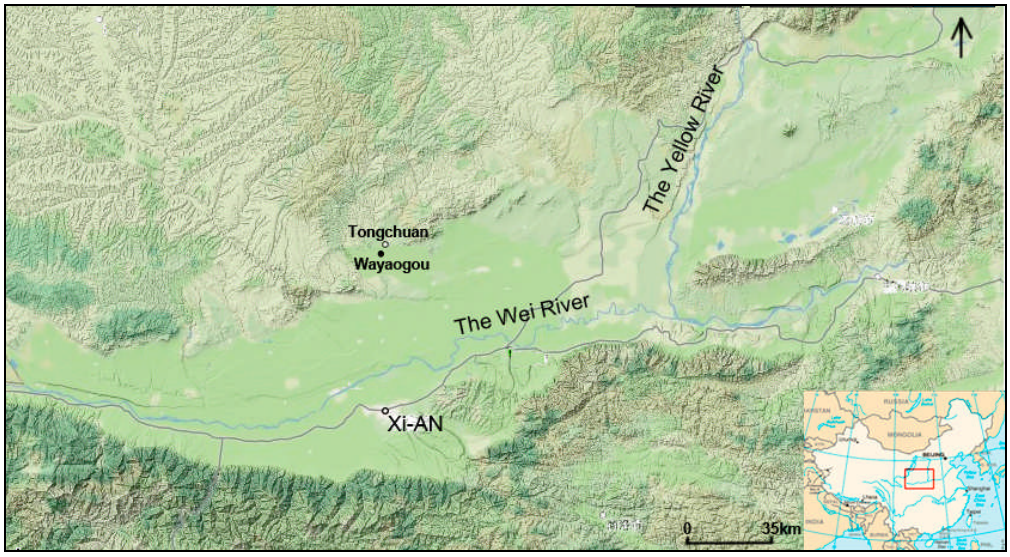


Fig. 2.1 The landscape of the Wei River valley (adapted from Google maps Terrain)

The Wei River valley belongs to temperate climate zone, with a longitude of 104-114° and latitude of 34-35°. It is characterized by a dry and cold climate and has unique hydrogeomorphic conditions, due to the fact that over 50% of precipitation occurs during July, August and September. It is much drier and colder in winter and the coldest month is January, with a temperature of -1 to -15℃. The summer is hot and rainy, and the total precipitation is between 50.8 to 63.5 mm, mostly falling in July and August. The climate is not unduly dry, but it is an area subject to severe and prolonged droughts as the loess is not suitable for storing water. On the loess plateau further north and west the climate becomes progressively drier and colder. Today,

millet, corn, wheat are among the main crops in this area and household livestock includes pigs, sheep, goats, cattle and chickens, while horses are accasionally raised in this area.

The environment in the Wei River valley is a little harsh today and not quite suitable for agriculture, but probably it was not the same case in ancient times. As a prominent tributary of the Yellow River, the Wei River played an important role in the emergence and development of Chinese civilization. Numerous Paleolithic and Neolithic societies have flourished in this area and a few dynasties, such as Han and Tang Dynasties, built their capitals in this region.

2.2 The Holocene climate and environment in northwest China

The climatic and environmental variations since the Holocene in China have attracted considerable scholarly effort in the past few decades, as global warming is becoming an important universal problem. Also, the climatic history of the Holocene is of great interest to archaeologists in understanding ancient societies.

At the beginning of the 1970s, according to historical and phenological records, Zhu (1972) first pointed out that the average temperature in the lower Yellow River area from 5,000 to 3,100 BP was 2℃ higher and the winter temperature was 3-5 ℃ higher than the present, which has been accepted by Chinese scholars in general for a long time. However, this proposition needs to be tested by other paleoenvironmental records, such as pollen evidence, ice cores and lake levels.

Systematic studies of palynology, paleobotany, paleozoology, paleopedology, paleolimnology, ice cores and see level fluctuations in China have been undertaken

since 1970s, which provided detailed information in terms of the timing of the climate and environmental variations in middle Holocene (Shi *et al.* 1993). It has been suggested that there were a series of climatic fluctuations of cold and warm, dry and wet, with both abrupt changes and gentle transitions, from 8,500 to 2,900 B.P. They can be divided into several phases: an unstable cold and warm fluctuation (8,500-7,200 B.P.); a stable warm and humid phase (7,200-6,000 B.P.); an intensive oscillation (6,000-5,000 B.P.); a substable and gently oscillating warm and humid stage (5,000-3,000 B.P.). Though this chronology needs more detailed work to be more convincing, it provides clues for us to understand the timetable of climate changes and its relationship to ancient society developments.

In recent years, new studies based on spore-pollen, paleolimnology, paleoglacial and ice core evidence have been undertaken in different areas and different valleys, which give us some regional patterns of the Holocene climate and environment change in China (An *et al.* 2004, 2006; Feng *et al.* 2006). An *et al.* (2000) argued that the East Asia Monsoon Maximum had a time transgressive nature from the northwest to the southeast. But this argument has been challenged by Feng *et al.* (2006) in terms of radiocarbon dating and sample representation. Given the uncertainties of chronologies, they proposed that the optimum occurred nearly contemporaneously at all sites in the Xinjiang region, in the Inner Mongolian Plateau and in the northwestern part of the Loess Plateau.

Although there is still some debate on the timing of the climate and environmental change between researchers, it has been generally agreed that there were a few climate fluctuations since the Holocene. This has conformed to the global natural trend, which has been reported from many places around the world. The outline of

global climate events has been summarized as following: a general trend of warming and increasing precipitation dominated the early Holocene; this trend reached its culmination in the Middle Holocene Climatic Optimum, which represented the warmest and wettest period of the Holocene in many areas; it was followed by cooler and drier condition, which characterized much of the Late Holocene period (Feng *et al.* 2006; Rosen 2007). The climate and environmental changes in northwest China conformed to the general outline of the global climate events.

Pollen maps of northern China provide a visual expression of palaeo-vegetation changes. From 8,000-6,000 B.P., a relatively open forest with *Pinus* as its dominant component developed in the southeastern Loess Plateau and northwest China, but it came to an end at about 4,000 B.P. On the other hand, warm temperature deciduous forest experienced a remarkable reduction during the last 6,000 years. Alpine valley *Picea/Abies* forest in the eastern Qinghai-Tibet Plateau developed in the early and middle Holocene, but started to decline at 4,000 BP, and has almost disappeared today (Ren and Beug 2002).

Recently, studies have related these climate events to the rising development of prehistoric societies. In northwest China, the flourishing of first Neolithic society (Dadiwan occupation) coincided with the dramatic warming and wetting period in the early Holocene. The period of Yangshao occupation was within the Climatic Optimum of the Northern Chinese postglacial, and Yangshao people experienced the warmest and the wettest period of the Holocene (Chang 1986), which was highly suitable for an agricultural economy. The river valley was covered by abundant vegetation and was rich in wild animals as well as food and other economic plants. Pollen studies suggested that this area was covered by grasslands and forests,

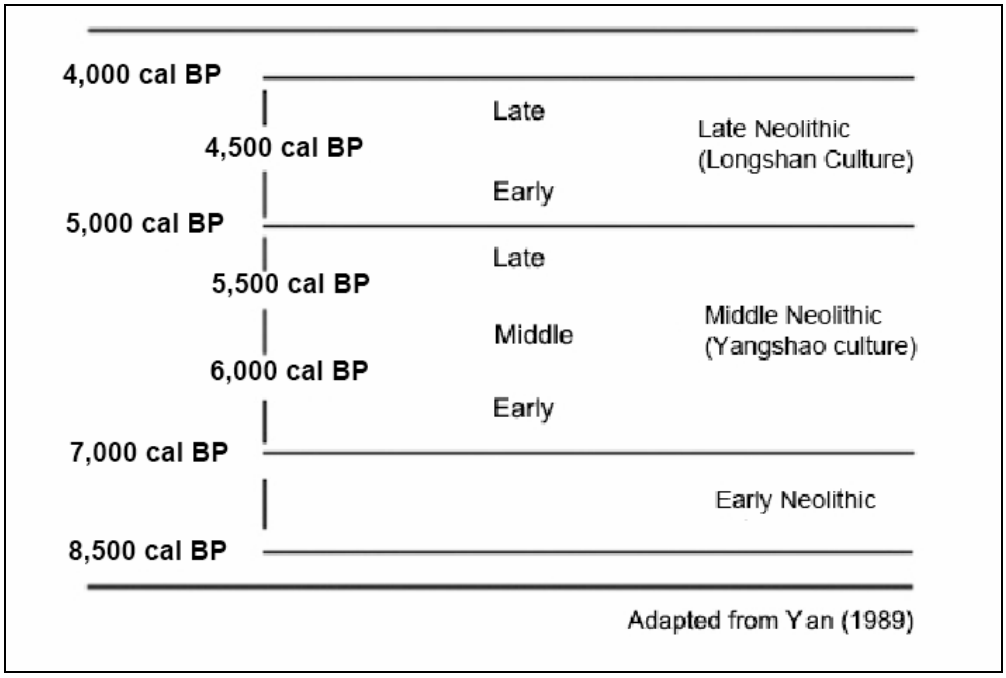
dominated by *Pinaceae, Artemisia* and *Quercus*, which indicate that the climate was mild and sub-humid and a little warmer than today (Zhang 2000). Following that, the late Neolithic (the Longshan period) witnessed a cold and dry climate and environmental deterioration.

An interaction between human beings and the environment in China during the Holocene has been proposed. The Holocene climate optimum (dominated both by warmest temperatures and by richest precipitation) witnessed the first flourishing agriculture society in China, but the expansion of farming and high-density settlements probably caused the decline in forests and woodlands from the middle to the late Holocene forest (Ren 2000). It has been argued that the late Holocene in northern China is characterized by deteriorating climate and reduction of farmlands which, however, coincided with the emergence of the first states in the Central Plain in China (Rosen 2007).

2.3 The chronology of the Neolithic in the Wei River valley

The Neolithic period in the Wei River valley has been divided into three phases: the early Neolithic, represented by the "Laoguantai culture"; the middle Neolithic, represented by the Yangshao period; the late Neolithic, represented by the "Longshan culture" (Yan 1989, 1990) (Tab. 2.1). The typical sites of the early Neolithic include the site of Dadiwan in Gansu Province, Beishouling, Baijiacun and Laoguantai in Shaanxi Province. The "Laoguantai culture", dating from 8,500 BP to 7,000 BP, is characterized by red and brown pottery and ground stone tools. It has been suggested that pigs and dogs were the main livestock of the "Laoguantai culture" and that human beings lived a sedentary life style (Chang 1986). The "Yangshao period" followed the "Laoguantai culture" and lasted from the fifth millennium BP the third

millennium BP. The sites, characterized by black-on-red polychrome pottery, are much more widespread and flourishing. Numerous sites belonging to the “Yangshao culture” have been excavated in the Wei River valley, including the sites of Banpo, Quanhucun, Kangjia, Anban and Wayaogou. Based on the pottery typology, the Yangshao period has been divided into three phases: the early, middle and late Yangshao. The “Longshan culture”, dating to 5,000-4,000 BP, represents the last Neolithic society in this area, just preceding the emergence of the first states in China. It is characterized by black pottery and has been divided into the two phases.



Tab. 2.1 The chronology of the Neolithic period in the Wei River valley

2.4 Previous studies of the “Yangshao culture” in the Wei River valley

The “Yangshao culture” is an archaeological term used by Chinese archaeologists to characterize the Middle Neolithic period of the middle Yellow River valley, dating

from 7,000 to 5,000 BP. Historically, the “Yangshao culture” was the first Neolithic community identified in China in the 1920s, and archaeological findings suggest that sites with Yangshao traditions were widely distributed in the northwest and Central Plain of China in the middle Holocene. The Wei River valley is one of the regions with high density of Yangshao sites and so far, numerous sites belonging to the Yangshao period have been recovered in this region (Fig. 2.2). It would be very interesting to intergrate the site distributions and locations with resource use pattern to investigate the function of different sites and variation of subsistence strategies.

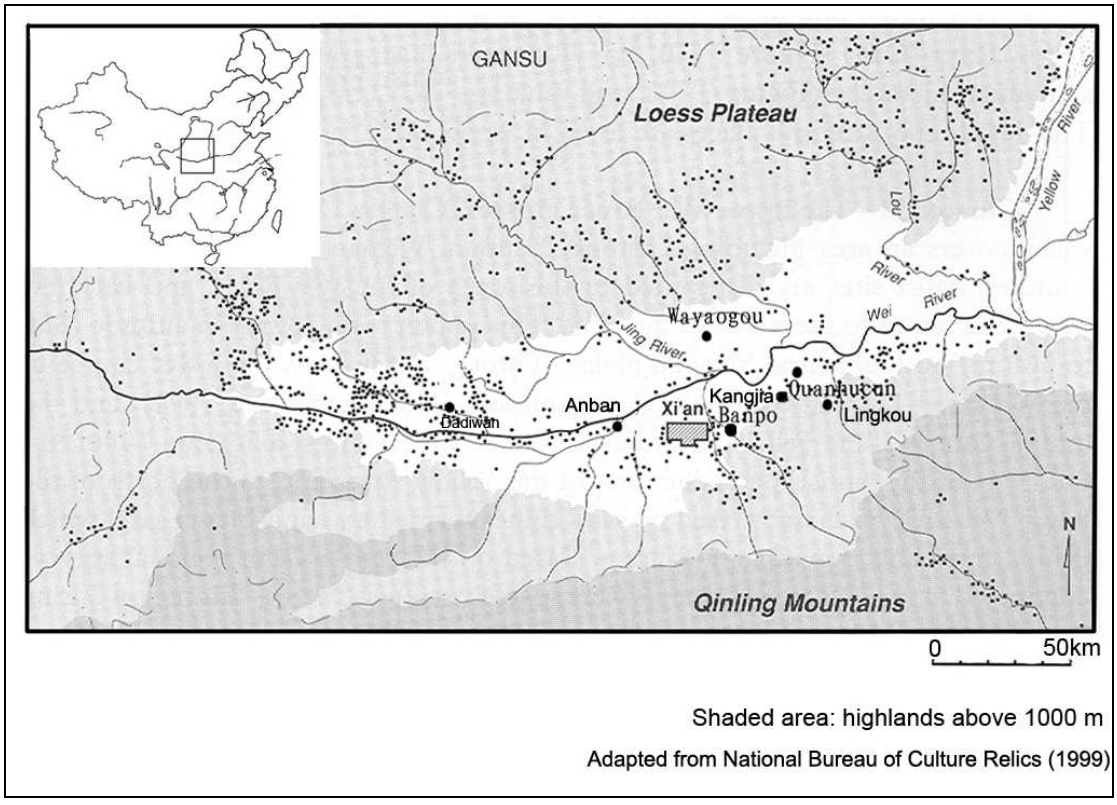


Fig. 2.2 The distribution of the Yangshao sites in the Wei River valley

Previous research on the “Yangshao culture” was mainly focused on its geographic distribution, and its relationship to preceding and subsequent communities. Archaeological work primarily addresses issues of stratigraphy, chronology and object assemblage analysis to define culture entities. It has been suggested that the origin and development of western and eastern regional traditions were different;

each probably had its own precursors and successors (Shao 1984). Also, the "Yangshao culture" has been broken into a few culture entities based on cultural attributes, and the relationships between them have been frequently discussed in the past (Zhang and Yan 1964; Yan 1989; Dai 1998).

For a long time, archaeologists in China paid much less attention to environment and subsistence economy studies. Only general outlines concerning subsistence are known to researchers: numerous species of animals were exploited during the Yangshao period, including sika deer, roe deer, water deer, red deer, leopard, wild horse, rhinoceros, antelope, rabbit, marmot, Chinese bamboo rat, mole rat, macaque, badger, raccoon, fox, brown bear, wild boar, turtle, fish, snail, and mollusc. It has been proposed that the dominant mode of Yangshao subsistence was agriculture: millet was cultivated by Yangshao people, and the most important domesticated animals of the Yangshao communities were pigs and dogs; cattle, sheep and goats are also recovered from the sites, but much less commonly (Li and Han 1959, Chang 1986: 112). However, systematic research of animal subsistence from one site has not been undertaken so far. Issues of the subsistence strategies and the ecological balance of the domestic and wild species have not been explored. And also, subsistence strategies changes from sites of different period, in the same region have not been investigated in detail.

2.5 Archaeological work at the site of Wayaogou

The site of Wayaogou is located in Huangbao Town, southwest of Tongchuan city, Shaanxi Province. It lies on the east bank of Qi River, which is one of the most prominent tributaries of the Wei River (Fig. 2.3; Fig. 2.4). Tongchuan County is located on the south of the transitional zone from the Wei River valley (Guanzhong

plain) to the Loess Plateau of Northern Shaanxi. Today, it is famous for its coal mine production. Geographic surveys were undertaken in the past and chipped stone tools have been collected. In the winter of 1973, archaeological survey was undertaken in the town of Huangbao by the Banpo Museum, and four Neolithic archaeological sites were discovered including: Lijiagou, lvjiaya, Wayaogou and Langzui (Banpo Museum 1984).

The site of Wayaogou was excavated in 1991 by the Institute of Archaeology, Shaanxi Province and the Cultural Bureau of Tongchuan County. The excavation of Wayaogou was a salvage project in advance of the construction of national grain depots. Surface survey indicated that the site covered an area of about 50,000 square meters, and 8,000 of them were recovered in 1991. Geographically, Wayaogou is located right on the terrace of the Qi River. The Qi River, flowing from north to south, is situated right in an open valley surrounded by loess plateau, extending 2,000 meters to the west and 1,000 meters to the east. The environmental variety around the site provides rich resource availability for people. Paleoenvironmental reconstruction will be undertaken in chapter 4 with the animal species recovered from the site, and the human ecological behaviour in terms of animal resources will also be explored.

Archaeological work suggested that the “Yangshao culture” layers lie directly below the disturbed soil layer in most parts of the site (personal communication from Wang, the director of the site excavation) and 27 tombs of pre-Zhou Dynasty were recovered in the west part of the site. A large quantity of archaeological features, artifacts of the Yangshao Period, have been unearthed, including 240 ash or storage pits, 21 house remains, 70 tombs (Fig. 2.5), and more than 3,000 artifacts, including

pottery, stone tools, bone tools and jade objects. At the same time, abundant plant and faunal remains were unearthed (Wang 1999. the final publication of the site is forthcoming). Over 20,000 fragments of animal bones, including mammals, bird, fish and shell remains, were present at the site, mainly from the ash pits, house foundations and ditches.

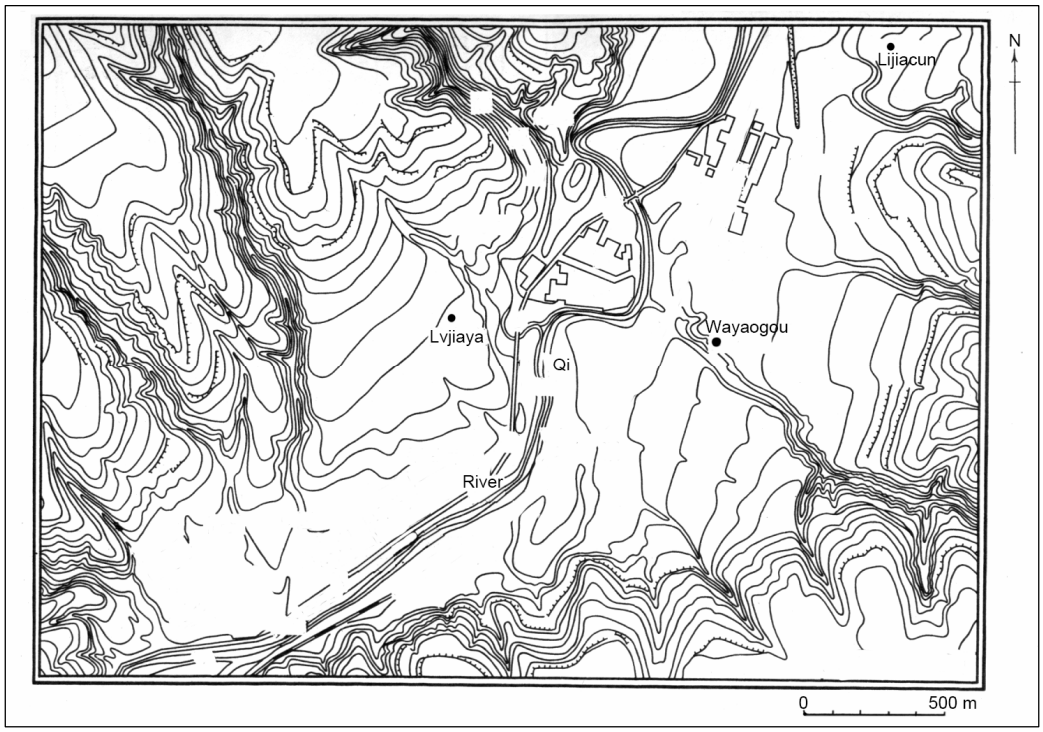


Fig. 2.3 Modern physiographic setting of Wayaogou

Twenty-one architectural foundations of the Banpo phase have been unearthed, with two patterns: one is rectangular in shape and semi-subterranean in structure; the other is rectangular in shape and an above ground structure. Each of them has a long, narrow entrance. One of them (F6) is about 70 sq. metres and the ground had been burned, with four thick pillars inside supporting the roof. All of this architecture was facing to the west except F6. Meanwhile, archaeological findings indicated that some cylinder-shaped pits were divided into two or three zones, with a size of 2-4 sq.

metres. It has been proposed by the excavators that these had functions associated with habitation (Wang 1999) as fire places have been traced within architectural remains and it seems there were postholes at the opening mouth of these pits. It is possible that these pits were used as shelters in the winter. The taphonomic processes and usage variations of these pits will be assessed in chapter 7.

Fig. 2.4 Photograph of Wayaogou (viewed from the northeast corner) showing its local setting, after backfilling

It is of great interest to find that a surrounding ditch in the northeast has been uncovered; it is about 25 m in diameter, 70 m in perimeter, and about 2 m in width and depth. There is an entrance in the north, with a width of 3 metres. A round pit lies by the entrance to the outside, with a diameter of 2.5 m at its mouth. Large quantities of faunal remains and burnt clay are present in the pit. A rectangular semi-subterranean architectural feature is by the entrance inside the ditch, with post holes and burnt clay. Also, there are two pits with burnt clays in the north of the ditch.

Two children buried in pottery coffins, were recovered in the north of this surrounding area, with a large number of artifacts, including pottery, jade, shell artifacts, a bone knife, a cluster of bone beads and bone decoration. Another nine child burials are also distribute around the big architecture. The layout of these relics indicates that the children were buried in a certain special cemetery. All the children were buried in the same way, using pottery as coffins, which is a typical style of child tomb during the Yangshao period. Seventy adult tombs were uncovered in the site alongside 46 children buried in pottery coffins.

Flaked stone tools, rather than ground stone tools, were recovered in large quantities at the site, which was quite different from other sites of Banpo phase in the Wei River valley. Assemblages with dominant flaked stone technology have been seen across much of northern China throughout the middle and upper Pleistocene. The only type of ground stone tool is the spade, which were probably used for digging pits as marks of such an implement have been recognized on the walls of the pits (Wang 1999).

The Yangshao period in the Wei River valley has been divided into three phases in all, lasting for about 2,000 years, from 6,900 to 4,900 BP. The pottery typology at Wayaogou indicates that Neolithic remains belong to the early phase (Banpo phase) of the “Yangshao culture” which is suggested to date from 6,900 to 5,800 BP by some scholars. Radiocarbon dating has been done at the site, showing that the remains at the site fall into 6,300-5,300 BP (Wang 1998). However, the pottery typology from the site has been compared to broader regional well-dated chronologies, and both shifts and narrows down the likely timeframe of occupation. The pottery typology studies indicate that the site represents a single component

settlement of the early “Yangshao culture”, representing a few hundreds years (Wang, personal communication with Wang), which is roughly between 6500—6000 BP. Hopefully, more samples can be collected from the site to have more C-14 dating in the future. In addition, a few Western Zhou burials were also recovered. As the stratigraphic information is available at this stage, it is reasonable to treat all the animal bone as a single unit for the analysis.

Fig. 2.5 Plan of the archaeological features at Wayaogou (each large grid square is 10 m^2)

2.6 Brief introduction to comparative sites

In order to have a thorough understanding of the animal domestication and subsistence of the Neolithic in the Wei River valley, a few sites with considerable faunal remains will be used for comparison, including Lingkou, Quanhucun and Donglongshan.

The Lingkou site is located in Lintong County, Shaanxi Province, and the excavation of the site was a salvage project undertaken by Institute of Archaeology, Shaanxi Province in 1994 and 1995 when an expressway was built. The archaeological report of the site was published in 2004 (Institute of Archaeology, Shaanxi Province 2004). Based on dating data and pottery typology, the excavator proposed that the archaeological remains from Lingkou belongs to a new period, Lingkou period, which is later than Baijiacun (Laoguantai) and earlier than the Baipo phase (early phase) of the middle Neolithic (Institute of Archaeology, Shaanxi Province 2004: 438-443). However, this proposition has not been well acknowledged, and the more accepted idea is that the Lingkou remains are not later than the Banpo phase which is contemporary or earlier than those at Wayaogou. The identification and quantification of large mammal species was undertaken in order to reconstruct the paleoenvironment and the results have been published briefly with the excavation report. During my field work in 2009, with permission from researchers at the Institute of Archaeology, Shaanxi Province, I measured pig bones that had been stored in the Research Base and recorded the linear enamel hypoplasia for pig mandibles (the methods will be discussed in detail in the following chapter), and the data will be used for the comparative study later.

Quanhucun is located in Huaxian County, Shaanxi Province, and it was recognized

and excavated in the 1950s and the site report was published in 2003. In 1997, new excavations were undertaken by the Institute of Archaeology, Shaanxi Province, which was a salvage project when an expressway was built. Archaeological remains mainly falls into the middle phase of the middle Neolithic, which is slightly later than those from Wayaogou. Large quantities of animal bones were recovered from the site by hand-picking retrieval methods. The report of the faunal remains, along with other archaeological remains has just been published (2011); the bones were identified and quantified systematically and some bones were measured, but not following the standards set by von den Driesch (1976). During my field work in 2009, I had the chance to re-examine the bones: the pig and sika deer bones were measured following von den Driesch (1976); mandible wear stages were recorded according to Grant (1982); linear enamel hypoplasia was recorded for pig mandibles. All these data will be used in my comparative study.

The Donglongshan site mainly dates back to the early Bronze Age. In order to study subsistence changes over time, the LEH on pig mandibles will be recorded and compared with those from Neolithic sites. In addition, published data of the taxa present at other Neolithic sites in the Wei River valley will also be drawn on for comparative studies, attempting to investigate the changes over time. These sites include Dadiwan, Jiangzhai, Baijiacun, Guantaoyuan and Kangjia. The justification of the time period of the sites and the faunal data will be undertaken when the data are presented and used.

CHAPTER 3
PROCEDURES OF ZOOARCHAEOLOGICAL ANALYSIS

3.1 Introduction

This chapter presents the details of all the methodological procedures applied to the animal bone assemblage from the site of Wayaogou. I mainly use standard current zooarchaeological approaches; one method which is less common (but increasingly applied) is Linear Enamel Hypoplasia (LEH), as explained below. The combined methods will produce data to address the following issues:

Taphonomy: attempting to define factors affecting animal bone survival and conditions, such as weathering, carnivore and rodent gnawing, burning and bone tool production.

Species present: first, I will give a list of species for zoogeographic interests; second, relative proportions of species will be quantified to establish the relative importance of animals in the economy and the balance between them. The Taxonomic Habitat Index (THI) is introduced in this study, trying to understand the ecological diversity and human hunting selection strategies.

Age profiles: age assessment is applied to pigs and deer. The cull patterns for pig will provide information to help assess domestic status and to investigate husbandry strategies applied to pigs. For deer, age profiles will be established to investigate whether special hunting strategies were used at the site.

Body part representation: to see what factors influence body part representation of certain animal. Retrieval methods, worked bone production, butchery and processing indicators will aid to the interpretation of body part representation.

Morphometrics: to assess the size of the most common taxa, pig and sika deer. For pig, comparative morphometric analysis informs on the domestic/wild status of the animals. Metric data from other sites in this region will be used for comparison and the size change of pigs from the early period to the late period will help understand the processes of animal domestication. For deer, metrics may yield information on adult sex ratios and can assess the environmental conditions and hunting pressures through deer time periods.

Linear Enamel Hypoplasia: mainly applied to pig remains from Wayaogou and a few other Neolithic sites in this region; to enhance knowledge of the domesticated status of pigs at the site, and to assess environmental condition and management strategies of pigs.

This chapter is divided into three parts: the first defines methods and procedures used for sorting, counting, recording and quantification; the second describes the criteria employed for identifying the species/taxa present at the site; the third justifies the application of using the linear enamel hypoplasia method. All sorting, recording and identification work was done in the Research Base of the Institute of Archaeology, Shaanxi Province, while faunal analysis was mainly undertaken at the Institute of Archaeology, UCL.

3.2 Sampling: retrieval and preparation

All the bones were retrieved by hand picking since this was a salvage project and no sieving was undertaken at the site. Some small mammal fragments have been collected from the site as part of sediment samples. As a result, this research mainly focuses on the medium and large sized mammals which are less likely to be biased by the collection strategy; the presence and absence of the small mammal species,

rather than the quantification of these species, was used to reconstruct the paleoenvironment since it is less biased by the retrieval methods.

First, all the bones with the same context number were gathered and put in one big basket. Then, all these bones were washed in the laboratory; some collections were covered by calcrete deposits which influence the identification and recording of the bones. These calcrete deposits were removed with metal tools and this work has been done by skilled technicians in Institute of Archaeology, Shaanxi Province. A time-consuming step here was re-joining bones with modern breakages; this means all elements from the same context were examined together to check whether two of more bones could re-fit. This was done by eye, and the experience was very important for overcoming the effect of new breaks. This method is a tradition in Chinese zooarchaeology and I was helped by local technicians. To some extent, this method ensured that fragments belonging to the same bone are not included in the MNE count more than once (see Quantification below). The problem is that it is possible that fragments from different contexts could originate from the same bones and it is more reasonable to examine all the fragments together. But this is not applicable in reality. This preparation, along with other processes including sorting, recording and counting, was undertaken on a context-by-context basis.

3.3 Sorting and recording

The sorting, recording and counting were done context by context, which means all the fragments from the same archaeological context were examined together. While there are clear benefits from examining all contexts together, this was not possible, but specimens between contexts were compared.

Sorting

The animal bones were sorted into identifiable and unidentifiable groups first. Identifiable means that the fragment can be identified to species, taxon group (e.g. deer), or taxon size class (e.g. large deer). It is necessary to identify to element before specimens can be identified to species. Identification potential is largely dependent on the conditions of bone fragments. At the site of Wayaogou, most bones are fragmented. Only small compact bones, such as carpals, tarsals and phalanges, calcaneum, astragalus were recovered in a complete state. Most long bones were only represented by distal or proximal ends and shaft splinters.

The identifiable bones were grouped into different body parts, including maxilla, mandible, atlas and axis, scapula, humerus, radius, ulna, metacarpal, pelvis, femur, tibia, fibula, calcaneum, astragalus and phalanges. Then all these identifiable bones were marked with the context number and a unique series number. It is therefore quite easy for us to relocate specimens for re-examination whenever needed.

The unidentifiable bones were sorted into six groups: horn core fragments, cranial fragments, teeth fragments, ribs and vertebrae (except atlas and axis), shaft fragments. Then these bones were sorted into three different size groups, represented by large size mammal elements (cow/red deer), middle size mammal (pig, sika deer) elements and small size mammal (dog, fox, water deer) elements.

Recording

All the bones were recorded using the York System for zooarchaeology (based on an Access database) designed by Dobney and colleagues (Harland *et al* 2003) and it has been slightly adapted for my data and site. For the identifiable bone, the following

categories of data are recorded, where applicable: context; series number; recovery; species; element; side of body; zones; state of fusion; taphonomy, including gnawing mark, texture, burning, completeness; general metric information, including weight and maximal linear dimension; presence and type of butchery and pathology.

Epiphysial fusion is presented using categories based on O' Connor (1989). Butchery is recorded on individual identifiable bones; details that were recorded included whether knife/chop/saw marks are present or a simple text description. Pathological evidence (except for LEH, see below) is routinely and quantitatively recorded, where present, on all recorded diagnostic zones and teeth. Measurements were done on all bones where feasible, using digital calipers to the nearest 0.1 mm. Measurements followed the standards set by von den Driesch (1976), and some others defined in the database by Dobney, and colleagues (Harland *et al.* 2003). For pig teeth, Grant's system of documenting wear stages (Grant 1982: 91-108) was used. Sika deer teeth were roughly aged based on the eruption and wear stages defined by Brown (1991) for red deer. Details of these methods will be described in chapters 5 and chapter 6.

The diagnostic zone approach was first introduced by Watson (1979), which is a good way to overcoming the problem of recording and counting the same bone twice. Dobney and Rielly has developed a new system of recording bone fragments (Dobney and Rielly 1988) which has been successfully applied to numerous archaeological assemblages. Standardized zones recording was provided in the York system database. In my study, diagnostic zone recording followed those defined by the York system, which is almost the same as those produced by Dobney and Rielly in 1988. Mandibles, scapula, humeri, radius, ulna, pelvis, femurs, tibias, metapodia, calcaneum, astragalus and phalanges were divided into different zones. The system

has provided pictures and drawings with numerical codes for the zone recording, which is quite efficient. Two sets of drawings were provided for the recording, according to the size of the animal. One set is for the large and middle size animals, including cow, horse, red deer, pig, sheep/goat and roe deer. The other one is for the small size animals, including dog, cat, hare, badger and beaver. Diagnostic zones were also recorded for sika deer using drawings for the large and middle size animals, and for water deer and musk deer using drawings for small size animals, since these two species are quite common in Chinese Neolithic sites.

For the non-identifiable bones, the following categories were recorded, context, recovery, size category, element category, including cranial, trunk or limb categories. All the unidentifiable elements were counted and some of them were weighed.

3.4 Animal bone identification

All the fragments were identified to species if possible, otherwise, to species group. Identification was mainly based on two approaches: first, modern reference collections were used for comparison. The reference collections of the Institute of Archaeology, UCL, deer collections in the Natural History Museum, UK, and some zoological collections in Shaanxi Provincial Institute, China, were consulted. The problem is that species may have undergone considerable morphological change over time; second, comparison with other archaeological material is probably the most useful approach to identify animal bones in my study as identification work has been done for lots of sites in this region and it is quite traditional to compare with other archaeological material, as modern reference collections were only collected in recent years. It is quite difficult to collect the skeletal material of some wild species in China because wild animal have rapidly disappeared during the last century due to

over hunting and ecological deterioration.

Pig

The difference between pig bones and other species present at the site seems most obvious. Pig bones are more robust than herbivores of similar size present at the site. The status of pig bones (whether wild boar or domestic) was investigated metrically, not using individual measurements, but instead plotting the size range of all the *Sus* bones to explore whether the range is likely to indicate wild, domesticated or coexisting populations at the site (and overlapping, indeterminates are expected). It has been argued that distinguishing domestic pig from wild boar based on other morphological criteria is not reliable as individual differences within domesticated population or wild population are also significant (Qi *et al.* 2006). Thus using size (on the total *Sus* bone assemblage) overcomes the problem.

Deer taxa

How to distinguish different species of deer remains at archaeological sites in China is always a tough problem. At least three size categories of deer were present at the sites in the Wei River valley: large size deer (150-200kg), including red deer (*cervus elaphus*), Mi deer (*Elaphurus dividianus*); middle size deer, mainly means sika deer (40-150kg); small size category, including roe deer (*Capreolus capreolus*) (30-40kg), water deer (*Hydropotes*) (about 15kg) and musk deer (*Moschus*) (6-9kg) (Sheng *et al* 1998).

The red deer and Mi deer were separated based on the antlers and their long bones were just grouped into large deer categories. The sika deer were identified mainly based on size, which is reasonable since it is the only middle size deer in this area.

The identification of small deer remains were mainly based on their antlers and size, and some measurement data from other sites were also consulted to distinguish different species of small size deer.

Cattle or water buffalo

Cattle or water buffalo remains at the site of Wayaogou are few. Water buffalo remains have been identified at sites of the Yangshao period in the Wei River valley before, so it is possible that *Bos* bone present at the site belongs to water buffalo. Cattle bones were simply identified to *Bos primigenius* at the site of Wayaogou since the criteria to distinguish bones between cattle and water buffalo remain unclear. Previous research indicated that domestic cattle did not exist until the late Neolithic in the Wei River. The origin of the cattle remains a problem in the region and the character of early, occasionally present, *Bos* remains is not quite clear.

3.5 Quantification

There are two common means used for quantifying relative taxonomic abundance of faunal remains: the first one is the number of identified specimens (NISP); the second is the minimum number of individuals (MNI). In order to address some taphonomic issues, another quantification method MNE (minimum number of elements) has been widely used in zooarchaeology. This unit quantifies the minimum numbers of each skeletal element (or portion of) for each taxon, thus avoiding the fragmentation effect which NISP includes (Lyman 1994:102-104).

The assumption for using the NISP method is that each identifiable fragment represents a different unit, which is quite problematic. The fragmentation of different species is different since factors such as butchery, trampling and weathering may not

affect all the species and elements equally (Grayson 1979). Many other problems with using NISP to measure taxonomic abundance have been described by Grayson (1979, 1984). The most serious problem suffers from the potential interdependence of skeletal remains, which brings out another problem that NISP may differentially exaggerate sample site across taxa. For these reasons, Klein and Cruz-Uribe suggest that NISP should not be used as a sole index of species abundance (Klein and Cruz-Uribe 1984: 25).

The MNI is produced by taking a count of the most common element, from either the left or right side of the body, for each species. The most important advantage of the MNI method is that it overcomes possible specimen interdependence and avoids counting the same animal twice. But a serious problem with MNI method is that it exaggerates the importance of rare species. Zooarchaeologists have found that MNI increases as NISP increase, which means that MNI has the same mathematical function as NISP (Grayson 1979: 224).

Although both NISP and MNI have many drawbacks, they are both commonly used methods to quantify relative taxonomic abundance. As both of them are quite problematic, another method, MNE (minimum number of elements) is also used in this study. As mentioned above, diagnostic zones of each specimen were recorded in the database. Each zone was assigned to certain parts of element: proximal end, shaft or distal end. The MNE of these body parts (proximal humerus, distral humerus, proximal radius, distal radius, etc.) is represented by the largest value of those zones that combine this body part. In order to assess the variations of the total number of elements, a standard animal was created. The body part representation of certain species was based on the frequency of diagnostic zones expressed as the percentage

of expected zones from complete skeletons from the number of animals, represented by the most common elements (Lyman 1994).

3.6 Taphonomic considerations and recovery bias

As mentioned above, the excavation of Wayaogou was a salvage project. Thus, no screens were used during the excavation and all the bones were hand picked from deposits as they were excavated (this is commonly the case in Chinese archaeology at the moment, since most excavations are salvage projects and archaeologists face high time pressure in the field). Watson (1972) suggested that many bone fragments less than 3 cm maximum dimension tended to be overlooked when only hand picking was used. Sparks (1961) demonstrated that the mollusc samples collected by eye, tended to have more specimens representing large size classes whereas the sample collected from a screen was dominated by specimens representing small size animals. Similar results were found for mammals by Payne (1972), who suggested that more of the large size taxa remains were found by hand picking whereas more of the small size taxa remains were found in sieves or screens.

The sediments in northwest China are ideal for the preservation and retrieval of animal bones as loess is prevalent. Actually, numerous specimens of small mammals, birds, and fish were collected by hand picking. Certainly, it is reasonable to assume that large quantities of small specimens were missed during excavations as they are less visible than large specimens. Obviously, the recovery techniques would influence the results and the representation of the samples collected by hand picking remains a problem. It should be borne in mind that recovery bias may influence the results during data interpretation.

The identification and recording of faunal remains at Wayaogou were mainly undertaken in the summer of 2008 and 2009, and included about 6,670 specimens of large mammals. Small mammals have also been identified and quantified although only the presence or the absence of the species will be used to reconstruct paleo-environment and vegetation around the site. Some species of small mammals, such as hare, may also have made contributions to subsistence. Bird remains were quite common in the assemblage and they were also recorded and measured systematically. The domestication process of chicken and its importance in the subsistence systems is an important topic for Chinese zooarchaeological studies. The status of chicken during the Yangshao period remains a question and the topic will not be discussed in detail in this thesis since the sample is not large enough. Systematic study on this issue will be undertaken in the future. Fish and shell remains were recovered but in small quantities, which may due to the recovery bias since they have more chance to be overlooked with hand-picking retrieval techniques. Thus, small mammal, bird and fish remains are probably highly misrepresented due to the poor recovery methods. Other taxa, such as reptiles, are not the focus of this study, since there is no sieving undertaken at the site. Hopefully, systematic study can be undertaken with ideal samples in the future.

3.7 Linear enamel hypoplasia

Linear Enamel Hypoplasia (LEH) is commonly visible on human and animal teeth, as lines or depressions in typical cases (Dobney and Ervynck 1998). It reflects a range of pathological conditions and could be used to indicate physiological stress and developmental health in humans and animals (Dobney *et al.* 2004). Previous studies suggested that it can be used to trace the process of pig domestication in

many Eurasian sites since domesticated pigs and wild boar shows different linear enamel hypoplasia index (Dobney *et al.* 2007). It has also been demonstrated that the frequency of LEH on pig teeth can throw light on environmental conditions and husbandry practices with some European case studies (Ervynck and Dobney 1999). It is potentially a good way to trace animal husbandry strategies and environmental conditions.

Birth and weaning are the causal agents of the two discrete peaks in the frequency distribution of LEH height recorded on the first permanent molar (M_1) of pigs. Stress, linked with temporal under-nutrition and unfavorable climate condition during the first winter of the pig's life, is also proposed as being the causal factor for a single LEH distribution peak noted on the second permanent molar (M_2). Feeding and living conditions during the second winter influence the pattern of LEH on the third permanent molar (M_3) of pigs.

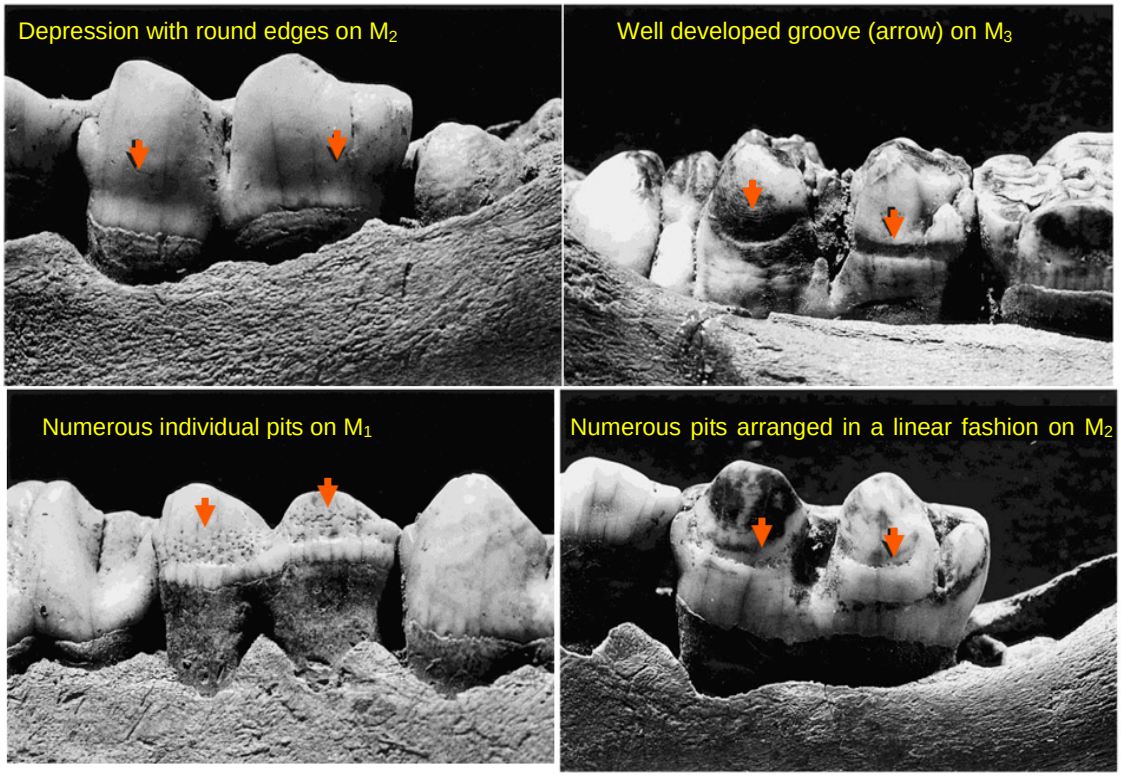


Fig. 3.1 The identification of linear enamel hypoplasia (from Dobney 1998)

The method for recording LEH has been described in detail by Dobney and Ervynck (1998), which is summarized as following: only the permanent molars of the lower jaw are selected for observation of LEHs for the following reasons: first, they can represent the whole developmental periods of the animal's life; secondly, they are usually more completely preserved at archaeological sites. Both the left and right sides of lower jaws are taken into account. Only the lingual surface of molars is examined as it is flatter than the buccal, which would facilitate height measurement. The LEHs on each cusp of M_1, M_2 and M_3 are recorded separately as each cusp develops independently and the position of LEH lines may be different on the anterior and posterior cusp and different events occurring during animals' life. Thus, LEH lines are recorded per individual cusp; with "a" indicating the anterior cusp of a molar, "b" the posterior one (or middle one in case of M_3) and "c" the posterior one of M_3.

LEH lines can be observed with the naked eye under strong oblique lighting, although a magnifying lens is used when necessary. Hypoplasia can be seen as depressions with round edges, well developed grooves, numerous individual pits, or numerous pits arranged in a linear fashion (Fig. 3.1). The distance between each LEH line and the cemeto-enamel junction on each cusp is measured along a perpendicular axis. As the LEH line is almost never a straight line, the measurement should be taken from the lowest point or the mid-point for the 'gross' lines.

As the LEH evidence could be removed by tooth wear, the eruption and wear stages of all teeth should be recorded according to Grant's system (1982), by which the age profile of the population is produced. If populations with dissimilar age profiles are compared, it is advised that interpretation is based only on fully erupted but unworn

teeth, which could be used for comparison with that based on the whole data set. This would adjust the interpretation of LEH results from sites of different pig age structures.

Having described the various zooarchaeological methods in this chapter, the following four chapters present results and discussion of how these methods have been applied to the faunal remains from Wayaogou.

CHAPTER 4

RANGE AND RELATIVE IMPORTANCE OF TAXA

4.1 Introduction

Faunal remains can be used to reconstruct the environments of sites since the presence or absence of certain species is closely related to the ecology or vegetation around the sites. Also, animal bones can provide a broad picture of the subsistence economy of ancient people as they reflect consumption patterns within sites, and the interactions between humans and animals. The archaeological assemblage is not only the outcome of human activities, but also of activities carried out by other agents. In general, faunal remains may shed light on ancient environment and the subsistence economies and human behaviour in the past.

The range and relative frequencies of taxa permit synchronic and diachronic explorations of ecology and habitats, environmental fluctuations and successions, taphonomic processes, recovery and sampling bias, and cultural differences. They are also used to evaluate the relative importance of animals in the diets obtained through various subsistence strategies. The change of relative frequencies of taxa through time is one of the most important means of identifying the process of animal domestication.

In this section, the range and relative importance of different taxa at Wayaogou will be presented mainly to account for two issues: first, the ecological diversity and environment around the site in the past: the presence and absence of certain species will define the ecology and reflect human hunting selection; second, the shift from

hunting to herding: the species spectrum change of Wayaogou and other sites in the Wei River valley will be plotted in chronological order to document the shift of taxonomic range exploited by humans, further to explore the shift from hunting to herding in this area.

4.2 Relative frequencies of taxa

The faunal assemblage from Wayaogou comprises a total of about 20,000 fragments of bones from mammal taxa (identified and non-identified). About 1/3 of those bones can be identified to species level. Some skeletal parts were identified to taxa as they are not readily identifiable to species, for example, many Cervidae bones. Therefore, I assign some of them which seem to belong to small size deer to the category small Cervidae, which includes roe deer, water deer and musk deer, and estimate the abundance of small *Cervid* in the same way that I estimate the abundance of an individual species.

Since the site was occupied for a relatively short time period and all the archaeological remains fall into the early phase of the Yangshao period, it is reasonable to analyze all the faunal remains as one unit. Published data for the taxa range from other sites in this region will be used for the analysis of ecological diversity, and the species spectrum and frequency change from early periods to late periods is used to document the shift of animal taxa exploited by human beings.

Tab. 4.1 summarizes the relative proportions of identified animal taxa by number of identified specimens (NISP). Twenty-five species of large mammals were recovered from the site and nine species of small mammals were present, including marmot, hare and bamboo rat and *Myospalaxv etc*. Sika deer and pigs make up about 80% of

the identified faunal remains, of which pig remains comprised 38.4% and sika deer 48.4%. Other species that comprises more than 1% of all the identified faunal remains include red deer (1.8%), roe deer (2.5%) and dogs (1.4%). Caprine bones were also present at the site. However, it is difficult to determine the status of these caprine bones due to the small sample size, and it is possible that these are specimen intrusive from a later period. Also, the criteria to distinquish the domesticated sheep/goat and other wild species in this region, such as serow, goral, are not well established.

Taxon	**NISP**	**%**
Horse	2	< 0.1
Cattle	32	0.5
Red deer	109	1.8
Mi deer	1	< 0.1
Large size deer	34	0.6
Sika deer	2947	48.4
Roe deer	154	2.5
Water deer	52	0.9
Musk deer	27	0.44
Small size deer	116	1.9
Pig	2338	38.4
Wild boar	3	0.1
Caprines	11	0.2
Gazelle?	6	0.1
Tiger	1	< 0.1
Dog	84	1.4
Dog family	14	0.2
Red fox	2	< 0.1
Weasel	4	0.1
Marten	1	< 0.1
Raccoon dog	3	0.1
Badger	63	1
Cat	15	0.3
Marmot	4	0.1
Hare	53	0.9
Beaver	12	0.2
Water shrew	3	0.1
Monkey	3	0.1
Total	**6094**	

Tab. 4.1 Relative taxonomic abundance of mammals at Wayaogou by NISP and NISP%

The presence of various taxa at Wayaogou indicates that a wide range of species was utilized: red deer, sika deer, roe deer, water deer, musk deer, rabbits and badgers *etc*. The relative proportions of different species suggest that, deer, especially sika deer, along with pig, played an important role in the subsistence economy although wild range of taxa was utilized at Wayaogou.

4.3 The ecological diversity analysis

Ecology is "the study of the natural environment, particularly the interrelationship between organisms and their surroundings" (Ricklefs 1973:11). Analysis of archaeological faunal assemblages provides clues about the nature of former environments and ecological diversity around the site (Armitage and West 1985). The basic assumptions of such analysis rely on that ecological requirements of species having not changed throughout human history, and that humans concentrated their subsistence efforts near their habitation. The ecology of organisms and their populations includes topics of species diversity and richness, preferred habitats and feeding strategies of different species, and ecosystem structure and food web (Reitz and Wing 1999: 85). In this section, the habitats and feeding strategies of animal species recovered from Wayaogou will be reviewed in order to shed light on the vegetation and environment around the site. Meanwhile, animal species diversity of different sites in the Wei River valley is compared and the taxonomic habitat index is defined to understand the ecological diversity and human economical strategies during the Neolithic. Since the relative proportions of different species were not only related to the ecology and habitats around the site, but also influenced by human selective practices, species richness will not be used to explore the ecological diversity in this study.

4.3.1 The distribution of feeding habitats

Habitat preferences and the distribution of animal populations are fundamental issues in ecology. Understanding habitat preferences is of great importance in the interpretation of ecological diversity and human economic strategies. Certain species are considered to have well defined habitat requirements and their presence in the fossil faunas is held to indicate the presence of that habitat type. In this section, the habitat preference and feeding habitats of species recovered from Wayaogou is reviewed to provide a general picture of the ancient environment (Tab. 4.2). The *Cervids* are the most common animal at the site and at least four species were present: red deer (*Cervus elaphus*), sika deer (*Cervus nippon*), roe deer (*Capreolus capreolus*), water deer (*Hydropotes inermis*). Musk deer (*Moschidae*), which is a close relative of *Cervus*, were also present in certain numbers. Various species of deer taxa point towards a mixed-vegetation environment with woodlands, forests, grasslands and grassy hillsides. Sika deer are mixed feeders and prefer to live on the boundary of forests and woodlands and require shade and coverage from the trees, but forage in open grass areas. They are absent in dense forests or corpses as is not suitable for running activities. The high proportion of sika deer remains suggests that significant cover of woodlands and grasslands existed around the site providing sufficient forage for the species. Their main diet includes grasses, some browse and even fruits. Red deer and roe deer require similar habitats as sika deer, generally on the boundaries between forests and denser woodlands, and grasslands and hillside grasslands are also preferred by them for foraging. Sika deer, red deer and roe deer often coexist in many areas in China today, as was probably also the case in the Neolithic. The three species of C*ervus* are among the most common wild animals recovered at Wayaogou, which suggests that forests, woodlands and grasslands were distributed abundantly around the site. Water resources were nearby as they are a prerequisite for the

animals to survive.

Cervids that inhabit temperate and boreal regions often exhibit seasonal migration between the summer and the winter range (eg. elk [*Cervus elaphus*] Adams 1982; sika deer [*Cervus nippon*] Igota *et al.* 2004). Many studies have reported that deer descend to areas of lower elevation in winter and return to summer ranges of high elevation in spring (Loft *et al.* 1984). Sika deer in northeastern China have different home ranges in winter and in summer (Sheng 1992; Sheng *et al.* 1998). In winter, they live on the sunny side of the mountains and dwell in places where the snow is shallow. In summer, they move to dense woodland browse in the grassland in the morning and afternoon.

The site is located on the transition zone between the river valley and the loess plateau in Northwestern China, and the landform is characterized by discontinuous hills today as was probably the case 7,000 years ago. This hillside was covered by trees, grasses and shrubs, providing ideal habitats for various deer species. The presence of *Capra* species and gazelles are usually interpreted as representing an open grassland environment.

Another important species that is useful for reconstructing ancient environments is water deer as they lives in the riverside and swamp regions with tall reeds and rushes. Occasionally, they are found in tall grasses on mountains and cultivated fields and open grasslands. River and swamp environments are essential for the survival of the species although they frequent various habitats. They also prefer warm and humid environments and the species cannot be found in northern parts of China today due to the climate change. The presence of water deer at Wayaogou suggests that water

resources were abundant around the site and there were rivers nearby since they are very dependant on water. The fauna of other water or river habitats such as beaver, water shrew and raccoon dog, were also recovered in certain numbers, which supports the proposition that there were plenty of water resources around the site. Fresh water existed around the site since fresh water fish and shells were also recovered in small quantities. It is possible that they are under-represented due to poor recovery methods. However, all these water adhering species occupied relatively small proportions in the faunal assemblage compared to the woodland and grassland-preferring species. It suggests that probably the landscape around the site was dominated by patchy clearings of forests, woodlands and hillside grasslands, and river resources, existed but not in significant numbers.

As mentioned above, the site is located on the right bank of the Qi River, which provides the most prominent water resource in this region today and this should have been the case in the Neolithic. The Qi River, and possibly its tributaries, provide sufficient waterside and swamp environment for many species, which occasionally became human prey. Some forest dwelling species, such as the tiger and the monkey were also present in small number at the site suggesting that possibly forests or dense woodlands was not far from the site.

Certain species can be used to make climate inference, for example, the bamboo rat, which is quite common at Neolithic sites in northern China, can only be found in the south today and their presence probably suggests a warm and humid climate during the time of deposition. Also, the frequent recovery of water deer remains indicates that the climate was warmer and moister in the Neolithic than today, and more water resources existed around the site at that time. The size change of sika deer can also

be used to indicate temperature and environmental change as will be discussed in detail in chapter 6.

To sum up, the area around Wayaogou during the time of deposition of the excavated fauna seemed to have been a mixed habitat of woodlands and grassy hillsides, as well as scrub or bushy areas with some types of fresh water.

4.3.2 The ecological diversity and human hunting selection

In order to have a thorough understanding of ecological diversity and human hunting selection strategies, the taxonomic habitat index (THI) is introduced in this study. The THI is a cumulative index that scores extant species for the range of habitats in which they were found (Andrew 1990). With this method, the ecological diversity can be interpreted based on the summation of the inferred ecological niches of the species composition of the faunas from sites (Andrew 1990: 165-176). The taxonomic habitat index can be obtained by combining the habitat indications of all the species contained in a fauna. This is a useful procedure since it only lists the species present, ignoring their relative abundances, which solves the problems that some published reports only produced species lists and the faunas were not quantified systematically. The habitats of these faunal species were established based on the ecological requirement of modern species (Sheng 1992, Sheng *et al.* 1998), and the animal diversity web of University of Michigan Museum of Zoology was also consulted (Animal Diversity Web, University of Michigan Museum of Zoology 2010). The habitat indication assessment of the individual species is made by scoring them for the range of habitats from which they have been recorded. For each species present in the assemblage, scores vary depending on the number of habitats occupied and the degree of preferences shown for each habitat, for example 1.0 if a single habitat is occupied, 0.5 each when two habitats are occupied equally, zero when a

habitat is never occupied and so on. For example, sika deer (*Cervus nippon)* is primarily a forest-dwelling deer that particularly prefers forested areas with a dense understory (Nowak 1991). However, these animals are able to adapt quite well to a variety of other habitats such as freshwater marshes and grasslands, so this can be expressed by scoring (out of 1) 0.6 for forests, 0.2 for marshes and 0.2 for grasslands. The Taxonomic habitat weightings for the large mammal and micro-mammal assemblage from the Wei River valley are summarized in appendix 4.1. All the species present at Wayaogou are scored according to their habitat preference. Then, scores are added together according to habitats and divided by the number of species, to give an average cumulative index per habitat.

Small mammals and large mammals were calculated separately in this study. Small mammals constitute a particular part of the fossil record, identified here as a group consisting of mammals less than 3kg in weight. This maily includes weasel, hare, water shrew and different species of rodentia, including steppe pike, giant flying squirrel, zokors (small rodent), bamboo rat and tundra vole. Various agents may responsible for assemblage accumulation and deposition of small mammals, which is quite different from that of large wild mammals, most of which arrived at the sites as a result of human hunting activities. Although the deposition of some species of small mammals, for example, hare, probably resulted from human hunting activities and related to subsistence, most of the small mammal bones may initially be deposited through accidental intrusion or by a non-human predator or as by-product of human habitat niches which created favorable contexts for the eventual deposition of microvertebrate remains. It is difficult to determine exactly which factors were responsible for the accumulation of the small mammal remains at the site. However, as with all other predator-accumulated assemblages, researchers have sought relevant

	feeding strategies	forest	forest boarder	Woodland	hillside shrub/ grassland	grassland/ open meadow	marsh	waterside shrub/reed	bamboo thicket	farm field	scrub desert
sika deer	grazer/browser	—				—	—				
water deer	Grazer							—		—	
roe deer	Browser				—		—			—	
musk deer	Browser	—						—			
red deer	grazer/browser	—		—			—				
pere David's deer	Grazer						—	—			
wild boar	Omnivorous	—						—		—	
badger	Omnivorous	—		—						—	
beaver	Omnivorous	—					—	—			
Cat	carnivore	—	—	—			—				—
Tiger	carnivore	—		—	—		—				
raccoon dog	omnivores	—	—				—	—			
weasel	Omnivorous	—								—	
Hare	Grazer					—	—			—	
water shrew	small mammal							—			
brown rat (*Rattus norvegicus*)	small mammal					—		—			
steppe pike (*Ochotona pusilla*)	small mammal					—					
giant flying squirrel (*Petaurista petaurista*）	small mammal	—									
zokors (*Eospalax fontanierii*)	small mammal			—		—				—	
bamboo rat (*Rhizomys sinensis*)	small mammal	—			—	—			—		
tundra vole （*Microtus oeconomus*）	small mammal					—		—			

Tab. 4.2 Generalized feeding strategies and habitat preference of various species at Wayaogou

large mammals	forest	Forest boarder	woodland	Underbrush	Hillside shrub/grassland	grassland/ open meadow	marsh	waterside shrub/reed	bamboo thicket	farm field	scrub desert
raccoon dog	0.4	0.3		0.1			0.1	0.1			
sika deer	0.6					0.2	0.2				
water deer								0.88		0.12	
badger	0.4		0.4							0.2	
roe deer					0.25		0.5			0.25	
musk deer	0.9							0.1			
red deer	0.2		0.7				0.1				
pere David's deer							0.5	0.5			
wild boar	0.5							0.3		0.2	
beaver	0.6						0.2	0.2			
cat	0.1	0.1	0.1				0.1				0.6
tiger	0.4		0.2		0.2		0.2				
total	**4.1**	**0.4**	**1.4**	**0.1**	**0.45**	**0.2**	**1.9**	**2.08**		**0.77**	**0.6**
average	**0.34**	**0.03**	**0.12**	**0.01**	**0.04**	**0.02**	**0.16**	**0.17**	**0.00**	**0.06**	**0.05**

Tab. 4.3 Taxonomic Habitat Index (THI) weightings for the large mammal assemblage from Wayaogou

small mammals	forest	Forest boarder	woodland	Underbrush	Hillside shrub/grassland	grassland/open meadow	marsh	waterside shrub/reed	bamboo thicket	farm field	scrub desert
weasel	0.6									0.4	
hare						0.4	0.3			0.3	
water shrew								1			
brown rat (Rattus norvegicus)						0.5		0.5			
steppe pike (Ochotona pusilla)						1					
giant flying squirrel （Petaurista petaurista）	1										
zokors			0.4			0.4				0.2	
bamboo rat	0.3				0.2	0.2			0.3		
tundra vole （Microtus oeconomus）						0.5		0.5			
total	**1.9**		**0.4**		**0.2**	**3**	**0.3**	**2**	**0.3**	**0.9**	
average	**0.21**	**0.00**	**0.04**	**0.00**	**0.02**	**0.33**	**0.03**	**0.22**	**0.03**	**0.10**	**0.00**

Tab. 4.4 Taxonomic Habitat Index (THI) weightings for the micro-mammal assemblage from Wayaogou

Fig. 4.1 Bamboo rat mandible with polish marks on the molar teeth and around the alveoli

signatures based upon skeletal representation, bone modification and archaeological context. Nine species of small mammal remains were recovered from Wayaogou and most of them were recovered from features such as ash pits and storage pits. Archaeological features, such as pits, wells and drains, may have acted as traps in the past, into which animals may have fallen and been unable to escape. Taphonomic studies suggest that butchery marks were very rare on the surface of small mammal bones and burnt marks were absent. Also, some small mammal bones were recovered with a relative complete articulation.

It can be proposed that most small mammal faunas were deposited by non-predator-related *in situ* (burrow) death, and the accumulation of most small fauna have little to do with human diet and subsistence. However, it is reasonable to credit the presence of hares and rabbits in the deposits to their having been a part of human diet. The presence of bones of marten and beaver, perhaps suggests human hunting activities for skin and fur. An interesting phenomenon is that two bamboo rat mandibles were polished (Fig. 4.1); whether this is commonly the case in Neolithic China needs more observation from other sites. Observation suggests

that butchery marks or gnawing marks were absent on the small mammal bones, which may indicate that the deposition of small mammals at the site has little to do with owls or other predator birds. How these small mammals arrived at the site remains an interesting question, and it is possible they are related to human consumption preference, which requires more contextual studies in the future.

The taxonomic habitat index for large mammals and small mammals were calculated separately in Tab. 4.3 and Tab. 4.4, since different agents contribute to their depositions. Small mammal fauna in the fossil record provide one of the principle methods for interpreting the ecology or habitat existing at the time the fossils were preserved. Their habitats represent more the ecology around the site, reflecting the habitats immediately adjacent to the site and not necessarily that beyond a radius of a few meters. In contrast, most large mammals were accumulated as human prey and their presence and absence indicates human hunting selections. The analysis of taxonomic habitat index of small mammals from Wayaogou suggests that grassland was the most common niche, followed by forest and waterside shrubs and reeds (Fig. 4.2). Wayaogou is located on the east bank of the Qi River and it is like a small basin, surrounded by hills to the east, the north and the west with an open mouth to the south. Mountains rise further from the site, in the north and west. Today the landscape is dominated by agricultural fields and hillside grassland and shrubs. However, one should bear in mind that farmlands and fields may provide similar habitat types for small mammal as that provided by grasslands. The analysis of small mammals suggests that grasslands and agricultural fields were quite close to the site, which provides ideal habitat niches for small mammals. The presence of waterside species seems closely associated with the Qi River itself.

The taxonomic habitat index of large mammals suggests that forest-adapted species dominated the faunal remains. Different species of deer were the main prey for human hunting activities, and most of them have forest habitats. The differences between the taxonomic habitat index of large mammals and small mammals indicate that probably most human hunting activities did not occur adjacent to the site and humans may have travelled a relatively long distance to acquire their prey such as sika deer in the woodlands and forests. However, it is difficult to determine how far away the hunting activities took place. The landscape may have changed a lot from the past to the present and it is possible woodlands or forests cover the hills and even further mountains. Thereby, it can be proposed that human economic activities were not restricted to the area adjacent to the site.

In order to evaluate species diversity of mammalian structure and the ecological diversity of Neolithic sites in the Wei River valley, the taxonomic habitat index of small mammals from Wayaogou and other sites in the Wei River valley is compared (Fig. 4.3). The THI is also plotted for large mammals to investigate the consistence and diversity of human hunting behaviours. Species lists of faunal remains reported by other researchers were used in this study, which includes Dadiwan (Qi *et al.* 2006), Guantaoyuan (Hu *et al.* 2007), Jiangzhai (Qi 1988), Quanhucun (Hu in press). One should bear in mind, for the interpretation of the ecological diversity of small mammals, that the sample size was relatively small at all sites, and no sieving was undertaken at these sites, so it is possible that the small mammal bones were under-represented with hand collection method due to the relatively small size of these bones.

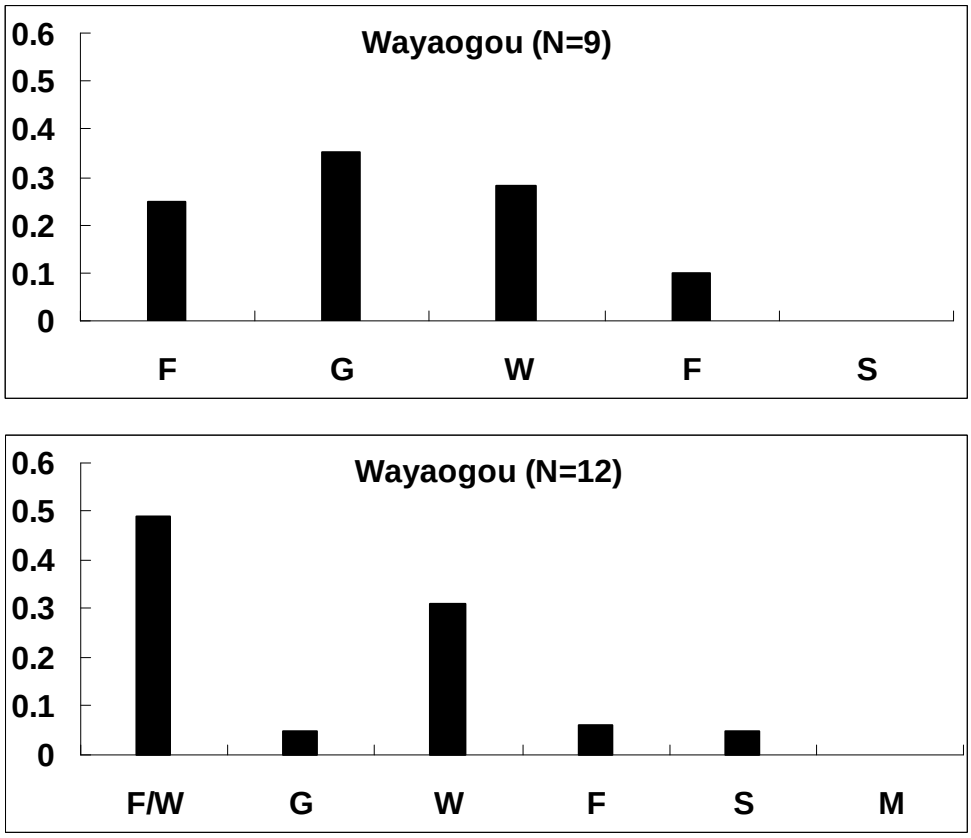


Fig. 4.2 Taxonomic Habitat Index (THI) for small mammals (upper) and large mammals (lower) from Wayaogou (F/W=forest/woodland; G=grass; W=water; F=farmland; S=scrub desert; M=mountain)

The cumulative taxonomic habitat index spectrum of faunal remains were plotted in chronological order, ranging from the early Neolithic to the middle Neolithic in northwest China. There are lots of variations and there seems no obvious pattern for the changes from the early Neolithic to the middle Neolithic (Fig 4.3), and this may be due to the small sample size and misrepresentation due to poor recovery. The small mammal habitat index allocates more taxa to the grass group (including grassland/open meadow, hillside shrubs/grassland) at all sites, except Dadiwan IV. The abnormal results for Dadiwan IV may be due to the small sample size as only two species of small mammals were recovered from Dadiwan IV, of which the giant flying squirrel represents a single habitat (forest). The taxonomic habitat

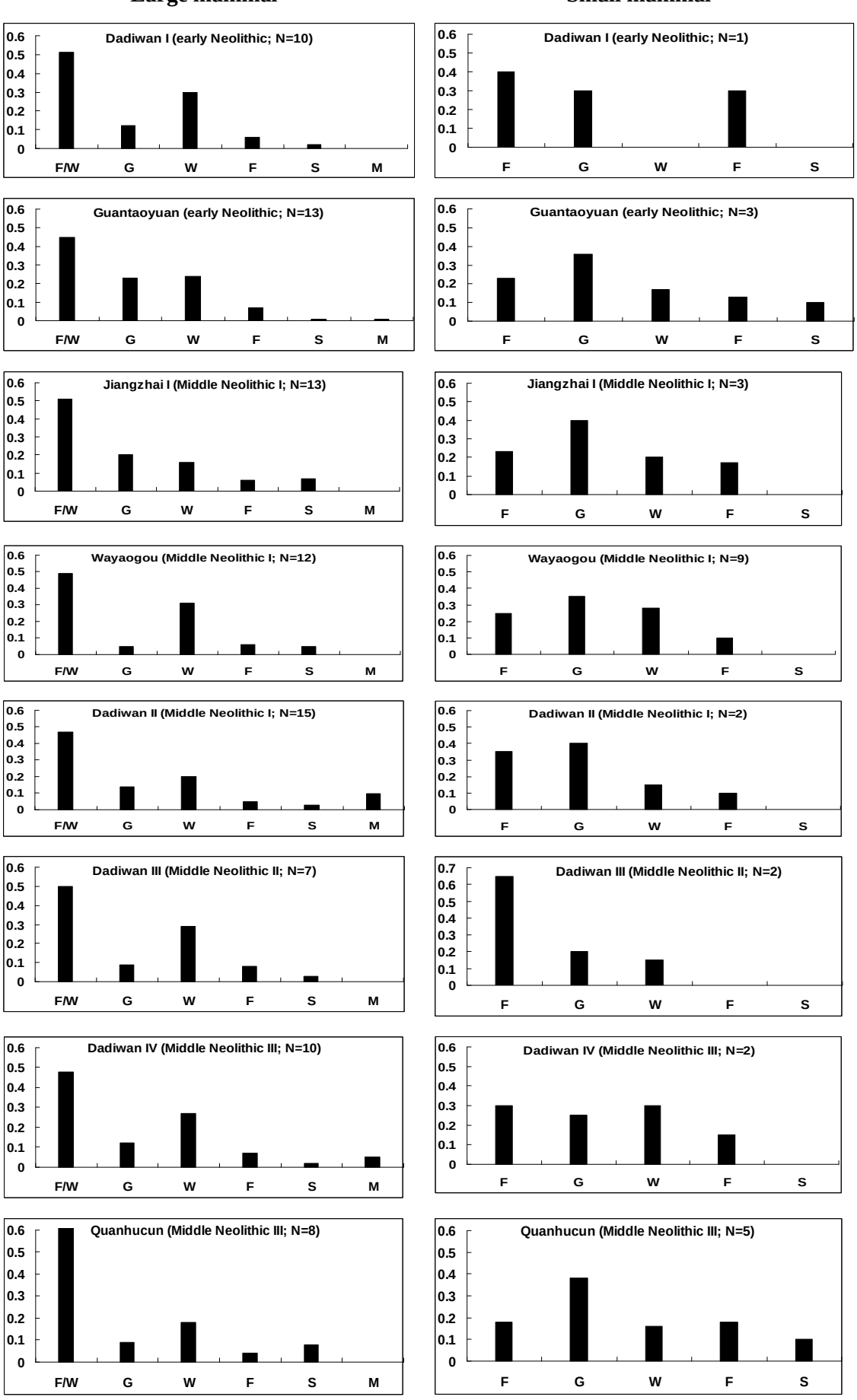


Fig. 4.3 THI for large mammals and small mammals from Neolithic sites in the Wei River valley (the sites are in chronological order, from early Neolithic to middle Neolithic); (code: F/W=forest/woodland; G=grass; W=water; F=farmland; S=scrub desert; M=mountain)

index of large mammals at all sites shows similar patterns: forests and woodlands species dominate the faunal remains at all sites in this area, suggesting that although grasslands or shrubs were abundant and close to the site, humans preferred to go further to the forests or woodlands to acquire hunted prey.

4.4 Species spectrum change

Relative proportions of mammalian taxa from Wayaogou are plotted in Fig. 4.4, based on percentage of the number of identified specimens per taxa (NISP). Although a wide range of species were hunted at Wayaogou, deer were among the main hunted taxa. At least six species of deer were hunted, including red deer, Mi deer, sika deer, roe deer, water deer and musk deer. Different species of deer occupied about 56% of the faunal assemblage. Pigs are the main domesticated species with 38.4%. The relative proportion of wild and domesticated taxa suggests that although pigs were domesticated extensively at the site, hunting activities remained an important part of the subsistence system.

The species spectrum seems dependant on not only environmental availability, but also the particular stage of subsistence development. Species spectrum change is a useful tool for documenting the process of animal domestication. The method depends on recording the changes of frequencies of different species which may reflect a shift from reliance on wild species to the domestics. As mentioned above, Wayaogou was relatively short-lived, representing the early phase of the Yangshao period, exploring changes within the site is impossible. However, comparisons can be made between different sites in this region. It has been suggested that the sequences for comparison should be derived from a limited geographical area to

eliminate regional variations (Davis 1987: 140). Thus, only the sites from the immediate Wei River valley are used to produce the patterns for examining species spectrum change, spanning the early Neolithic and the middle Neolithic. By comparing the patterns of the relative proportions of wild and domesticated species between Wayaogou and other sites in the Wei River valley, certain issues, such as the shift from herding to husbandry and the process of animal domestication, can be explored.

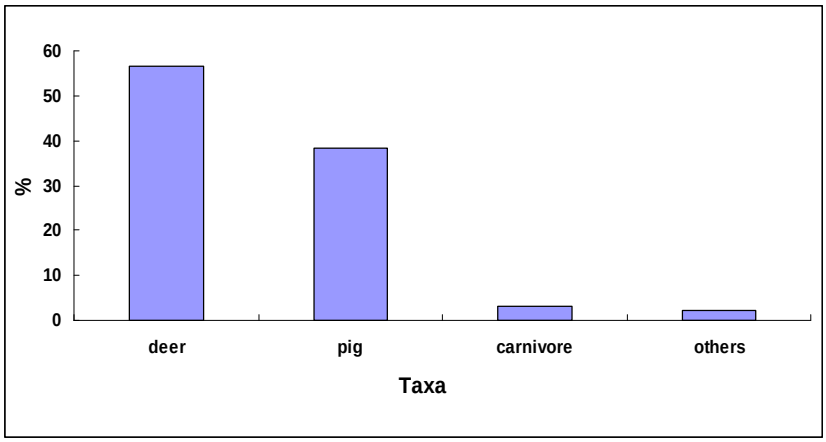


Fig. 4.4 Relative proportions of mammalian taxa from Wayaogou, based on NISP % (Total NISP=6094)

The percentage of the main taxa from Neolithic sites in the Wei River valley is plotted in Fig. 4.5 in chronological order (the original data for the taxa representation from these sites are in appendix 4.2). Deer taxa and pigs are the main taxa recovered from all sites. Other taxa, such as cow, water buffalo, *Caprinae* and *Antelopae* are also present in small quantities. Percentages have been calculated for deer, pig, cow, water buffalo, *Caprinae* and *Antelopae* from the NISP of each taxa/species divided by the total number of identified species of large mammals at each site, since these species/ taxa are assumed to be more

related to subsistence.

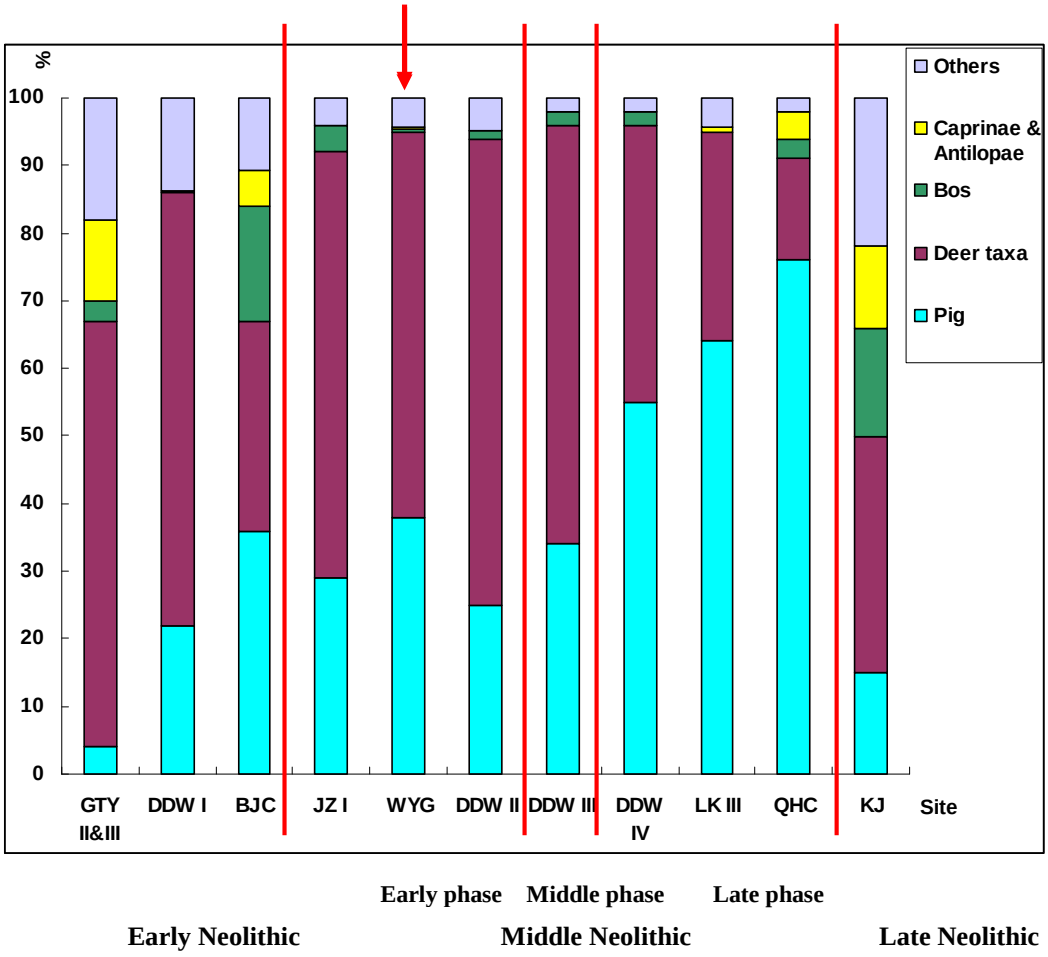


Fig. 4.5 Diachronic changes in the proportions of pigs, deer and other taxa at Neolithic sites in the Wei River valley; sites (GTY=Guantaoyuan; DDW=Dadiwan; BJC=Baijiacun; JZ=Jiangzhai; WYG=Wayaogou; LK=Lingkou; QHC=Quanhucun; KJ=Kangjia) are plotted in chronological order from the left to the right, with Wayogou towards the middle. The percentages of wild taxa and pig are shown; all large mammal taxa are included except carnivores

The patterns suggest that the percentages of pigs show a continued increase from the early periods to the late periods, whereas the deer percentage generally declines (Fig. 4.5). Deer dominate all the faunal assemblages in the early Neolithic and the same pattern can be observed at all sites of the early phase of the

middle Neolithic except Baijiacun, where both deer and pig remains exploited equally. Deer remains still outnumbered pigs in the early and middle phase of the middle Neolithic (Wayaogou, Dadiwan II, Dadiwan III).

The patterns change in the late phase of the middle Neolithic when pig remains dominate the faunal spectrum at all sites (Dadiwan IV, Quanhucun, Lingkou III). The site of Dadiwan was occupied for a relatively long period, from the early Neolithic to the middle Neolithic, and similar pattern can be observed within this single site, with an increasing percentage of pig remains and a decreasing percentage of deer; deer outnumbers pig in the late phase of the middle Neolithic (Dadiwan IV). The change in frequencies of ungulate species from the early Neolithic to the middle Neolithic probably reflects a shift from hunting to herding, which indicates that domesticated species (pig) became the reliable meat source for humans. It is unlikely that this Neolithic shift represents an extinction of deer, since all the deer species were still recovered in these post-Neolithic sites, and survives to this day. Faunal remains from the Kangjia site (Liu *et al.* 2001) suggest that probably pig husbandry shrank with the expansion of deer hunting in the late Neolithic (Fig. 4.5). This is such a note-worthy pattern and probably reflects the subsistence strategy change through time in this region (see detailed discussion in chapter 8).

Fig. 4.5 suggests that the change towards the increase of domesticated species was not a sudden transformation. In the early phase of the middle Neolithic, there was still much hunting of deer. It is not until the late phase of the middle Neolithic that pigs became the main meat sources for ancient people. However, the species

spectrum at these sites shows high variation, which may be attributed to environmental variations between the sites. For example, a large quantity of water buffalo remains was recovered at Baijiacun, which reflects the local environment. The Baijiacun site is located on the north bank of the Wei River valley and the water resources were probably more abundant here than at other sites in the Neolithic, providing an ideal environment for the survival of water buffalo. The relative large quantities of water deer also suggest sufficient waterside and swamp environments around the site. The domestic status of water buffalo at Baijiacun has been proposed by researchers (Zhou 1994); however, this can be questioned since very little evidence has been provided to support the suggestion. The domestic status of sika deer in the Neolithic China has also been proposed by some researchers, but it is highly doubted by most archaeologists (Zhou 1983; Qi 1988). There is no evidence supporting the idea of the domestication of sika deer, and no other species of deer has been proved to have ever been domesticated. None have become livestock in China, although sika deer, along with other deer species have been occasionally tamed and raised in farms today, and possibly in the past. Historic literature suggests deer hunting was an important amusement for the nobles during the Shang Dynasty.

The species spectrum and proportion of faunal remains at these sites suggests that it is only in the late phase of the middle Neolithic (the sixth millennium BP) that the products of hunting ceased being a major component of the diet of people inhabiting the Wei River valley. The decrease, but continue presence, of deer bones at these sites suggest that older patterns of reliance on the hunt for animal protein had not disappeared.

4.5 Discussion

Analysis of the relative taxonomic abundance at Wayaogou suggests that deer and pig were the most common taxa at Wayaogou, although at least 30 mammalian species were recovered from the site. Various species present at the site point to a mixed habitat of grasslands, woodlands, scrub and bushy areas, and some types of fresh water habitats. The taphonomic habitat index (THI) of small mammals suggests that grasslands or hillside shrub/grasslands are abundant and close to the site; however, human hunting activities mainly occurred in the forests and woodlands which seem further from the site. It is possible that hunters travelled a relatively long distance to acquire their preferred prey.

The animal spectrum was put in a broader context by comparing Wayaogou to other Neolithic sites in the area, and a sequence was derived which generally shows the following trend: the relative proportion of deer decreased from the early phase to the late phase of the Neolithic, whereas pig increased. This probably reflects the process of pig domestication and the development of pig husbandry during the Neolithic in the Wei River valley, and will be further explored in chapter 5.

CHAPTER 5
PIG DOMESTICATION AND HUSBANDRY STRATEGIES

5.1 Introduction

Pigs definitely played an important role in the subsistence economy as they made up 38% of all the faunal remains at Wayaogou. The pig was the most common domesticated species (the status will be addressed in detail below), and studies of pig husbandry strategies is an important aspect to understand the economic systems during the Neolithic. The beginning of pig domestication can be traced back earlier in the Wei River valley, and pig remains from the Dadiwan I (the early Neolithic) probably represent the early stages of pig domestication in this region. But with serious flaws in the faunal studies at Dadiwan (Qi *et al.* 2006) which have been pointed out in Chapter 1, pig domesticated status at Dadiwan I needs new studies to be more convincing. And also, the systematic studies on the process of pig domestication in the Wei River valley are missing. Thus, the status of the pig remains at Wayaogou still remains an interesting question. Furthermore, if the pigs at the site are found to be domestic, what kinds of husbandry strategies were practiced? Hence, my research in this chapter attempts to trace the evidence of pig domestication and husbandry regimes in the region. With these research themes, the analysis of pig remains from Wayaogou will undertake the following aspects: 1. taphonomic consideration; 2. metric analysis; 3. cull pattern; 4. linear enamel hypoplasia analysis. Published data, along with data collected during my field work from other sites, will also be used for comparisons, which would help understand the faunal pattern changes and trends through time.

5.2 Skeletal element representation for pig

Body part representation can be used to trace factors that affect bone survival and conditions. The taphonomic bias, retrieval bias, and even bone tool industry could influence the survival of different body parts of different species. In the York System (database, Access based), diagnostic zones are recorded for idenfifiable specimens, and each zone is assigned to certain parts of elements, e.g. proximal end, distal end (Harland *et al.* 2003). The mandibles are also recorded with different diagnostic zones, and each zone is assigned to anterior or posterior part. Loose teeth were not counted for the body part representation study, since it is quite possible they represent duplicated elements with the mandible. For the maxilla, only the specimens with at least three teeth were counted, and small fragments or loose teeth were not counted for the body part representation study. This is also to avoid the duplication of elements. The minimum number of element (MNE) of each body part (anterior mandible, posterior mandible, proximal humerus, distal humerus etc.) is achieved by counting the number of the most frequently present zones. Fig. 5.1 plots the % survivorship of different body parts for pig (the original data are in appendix 5.1), showing that the anterior mandible of pig survived best at the site, followed by the distal humerus, ulna articulation, posterior mandible, scapula, pelvis, proximal radius, distal tibia, astragalus and metapodia, which roughly falls into the typical pattern of natural survival of body parts of the pig (Ioannidou 2003).

It has been suggested that structural density of the bone is a possibly important mediating factor between taphonomic processes and frequencies of body parts representation (Guthrie 1967; Lyman 1994: 235). The survivorship of different

body parts, due to the effects of some taphonomic processes, such as dog and people ravaging and transport of skeleton element, is closely related to the bone mineral density (Brain 1967, 1969; Voorhies 1969; Lyman 1994: 235).

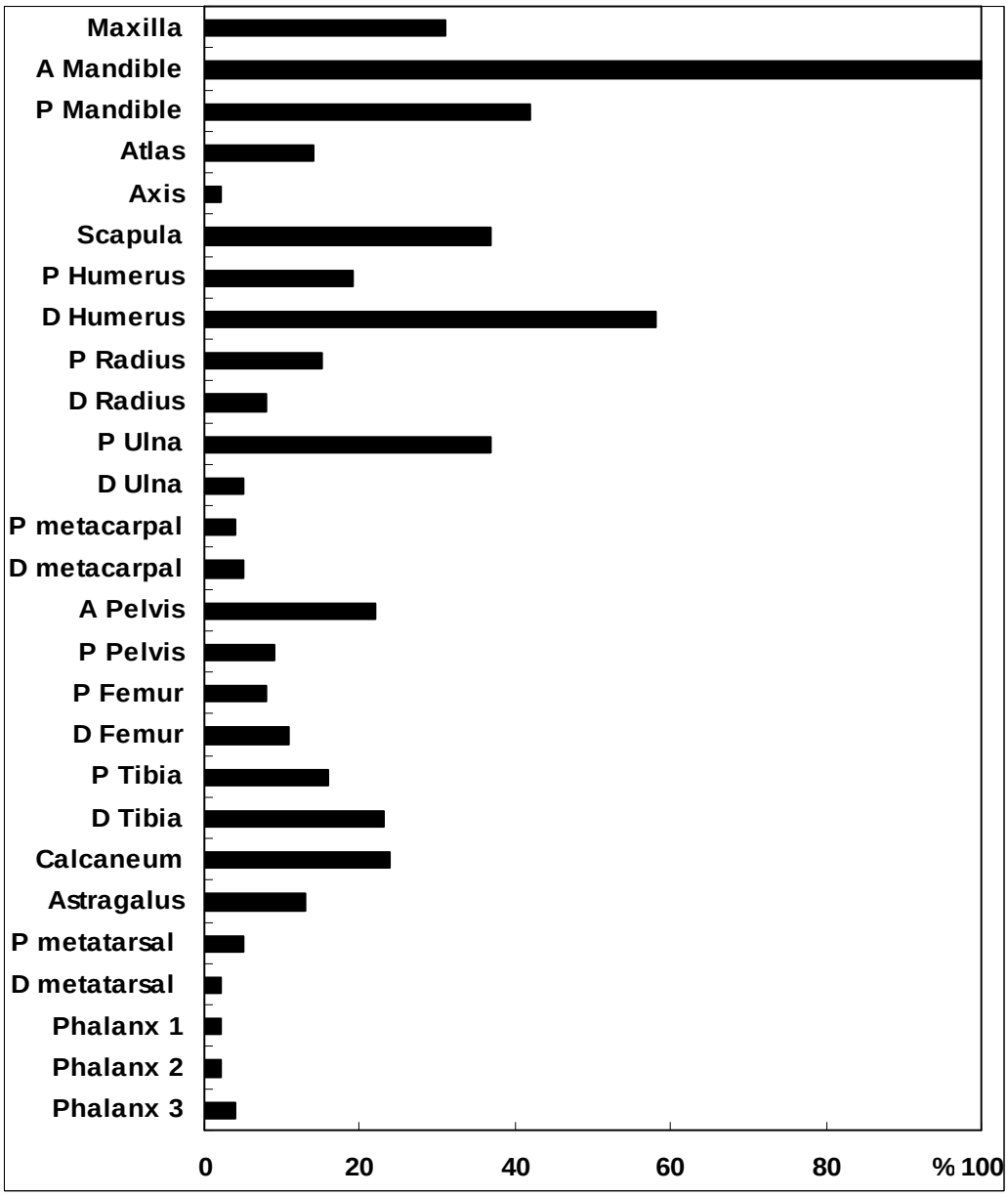


Fig. 5.1 Body part representation for pig at Wayaogou〔A=anterior; P (mandible) =posterior; P (postcranial) =proximal; D=distal〕

The % survivorship values of pig skeleton part zones from Wayaogou are plotted against bone density values for pig (Fig. 5.2). The density values for pig body

parts were based on the data provided by Ioannidou (2003). Fig. 5.2 shows that there seems to be no linear relationship between the frequencies of pig body part zones from Wayaogou and bone structure density values for the species.

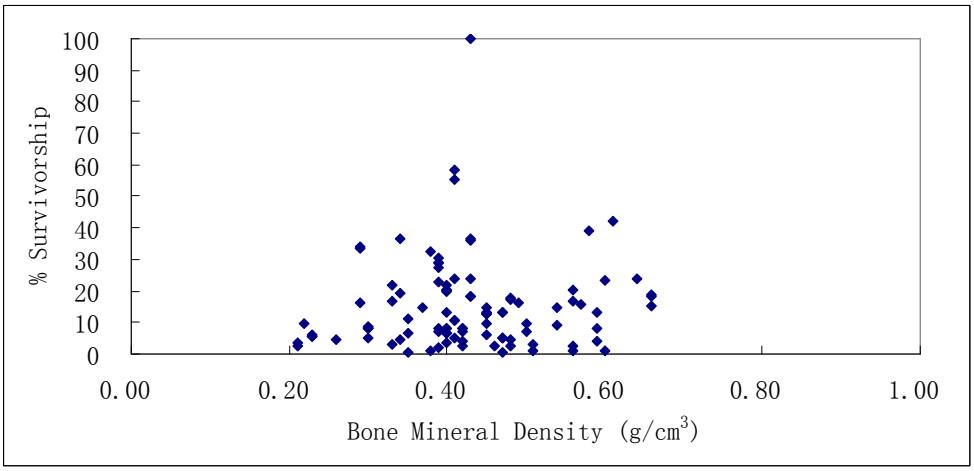


Fig. 5.2 Scatterplot of % survivorship of pig skeletal element zones from Wayaogou against pig bone mineral density values (bone density values following Ioannidou 2003)

This pattern can be explained if taphonomic processes or human or animal activities conducted on animal bones were not all mediated by bone mineral density. The activities humans conducted on animal bones can be very complex, and also, other factors such as weathering and rodent gnawing, and sediment overburden may have influenced the survival of different body parts at the site. The results suggest that a wide range of factors had influence on the frequency of pig skeletal parts and it is difficult to trace what factors have contributed most to the body parts representation. Another possibility is that the bone density values based on the studies of modern samples from the Near East do not well represent the values of pig populations in China due to environmental variations. It is possible that a different pattern will be inferred if bone density values are derived from local pig populations. Unfortunately, density value data of Chinese pig populations are not available at present.

Retrieval methods also seem to have influenced the body part representation and retrieval bias could be examined by the survivorship of certain elements. For example, it is interesting to note that the % survival for pig metapodial and phalanges was quite low at Wayaogou, both with less than 10%. This could be explained by recovery bias having affected the representation of body parts; some phalange were missing during the excavation as they have more chance of being overlooked with hand picking due to their small size.

5.3 Morphometrics of pig

5.3.1 The Metric analysis and comparisons of M_3

Size reduction in teeth is one of the characteristics that have frequently been used for identifying the presence of domesticated pig on archaeological sites (Flannery 1983), especially, the size change of the third lower third molars (M_3) of pig over time has been frequently used to document the process of domestication. In order to determine the status of pig populations from Wayaogou, the lengths and greatest breadths of the M_3 are plotted in Fig. 5.3, and also, data from the site of Jiangzhai (Qi 1988), Quanhucun and Donglongshan are plotted in the same graph to explore the size change through time. The size measurements of M_3 for pigs were also been undertaken at Donglongshan and Quanhucun during my field work in the summer of 2008 and 2009.

Fig. 5.3 shows that most M_3 length measurements from Wayaogou are between 36 and 40 mm, which fall in the range of overlap for wild and domestic pigs (Hongo and Meadow 1998). Also, a relative small proportion of pigs have length measurements greater than 40 mm and a few of them are less than 35mm. There is

a relatively small size range of the length of M_3 at Wayaogou, which may be explained by the fact that the archaeological remains represented a relative short period.

Published data from Jiangzhai are plotted for comparison. Archaeological remains from Jiangzhai have been divided into five phases, ranging from middle Neolithic (Yangshao period) to late Neolithic (Longshan period). The length measurement data are mainly from phase 1 and phase 2, which coincide with the middle phase and late phase of the Yangshao period (Qi 1988). Fig. 5.3 shows that similar patterns for M_3 length measurements exist at the Jiangzhai site, with a concentration of M_3 between 35-40 mm, with a few greater than 40mm or less than 35 mm. It is noticeable that the breadth measurements at two sites are quite different and it seems that those from Jiangzhai are larger than those from Wayaogou. The reason for this difference remains unexplained. Archaeological remains from the Quanhucun site mainly belongs to the middle phase of middle Neolithic, and Donglongshan represents early Bronze Age remains. It is obvious that the size ranges of M_3 from Quanhucun and Donglongshan are much smaller than those of Waoyaogou and Jiangzhai, with most of them falling in the range between 30-35 mm. Thus, the general trend can be inferred that the M_3 of pigs reduced from early periods to late periods. It is interesting to find that there is a significant size reduction of M_3 from the early phase to the middle phase of the middle Neolithic. Pig remains from the sites of Wayaogou and Jiangzhai may represent the early stages of pig husbandry, which is quite different from later periods. However, the sample size in this study is quite small, and a more convincing conclusion could be inferred with more data from other sites in this region added in.

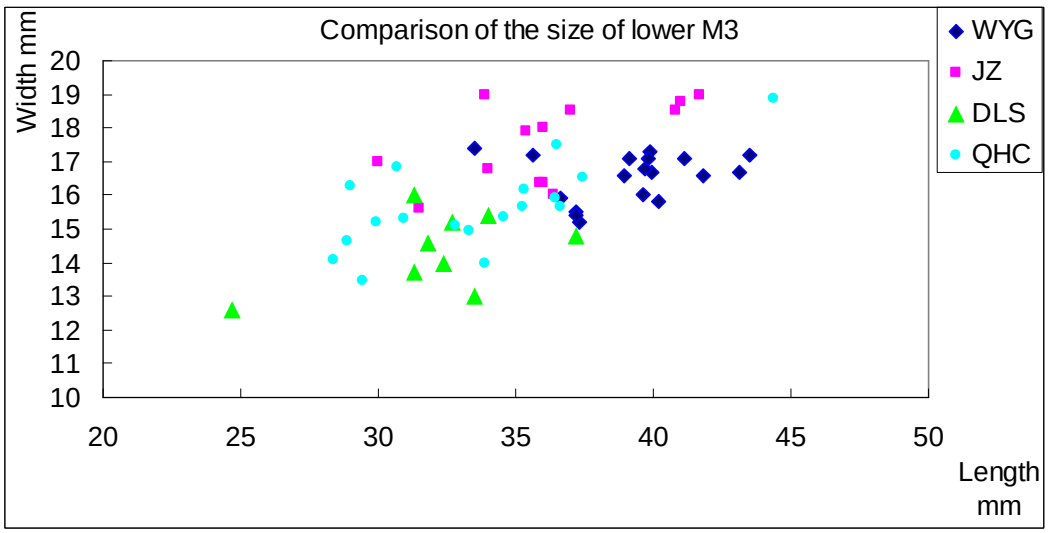


Fig. 5.3 Comparison of the length and width of the lower M_3 of pig from Neolithic sites and early Bronze Age sites in the Wei River Valley〔WYG=Wayaogou (N=18); early phase of middle Neolithic; JZ =Jiangzhai II (N=13) (early phase of middle Neolithic); QHC=Quanhucun (middle phase of middle Neolithic); DLS=Donglongshan (N=9) (early Bronze Age)〕

To gain a broad picture of M_3 size change, The lengths of lower third molars from sites of different time periods in the whole country are plotted in Fig. 5.4 (the original data are in appendix 5.2), spanning from the Paleolithic period to the Bronze Age. Data of three Paleolithic sites from northern China are included in this figure: Gongwangling in Shaanxi Province (Zhou 1964), Zhoukoudian in Beijing (Young 1932) and Jinniushan in Liaoning Province (Institute of Paleontology and Paleoanthropology 1959). It is obvious there is a reduction trend for the length of M_3 from Paleolithic to Bronze Age. The lengths of M_3 recovered from Paleolithic sites range from 40 to 45 mm with an average length greater than 40 mm. The M_3 length measurements from early Neolithic sites have a wide range, from 37 to 47 mm with an average length greater than 40 mm. The average length

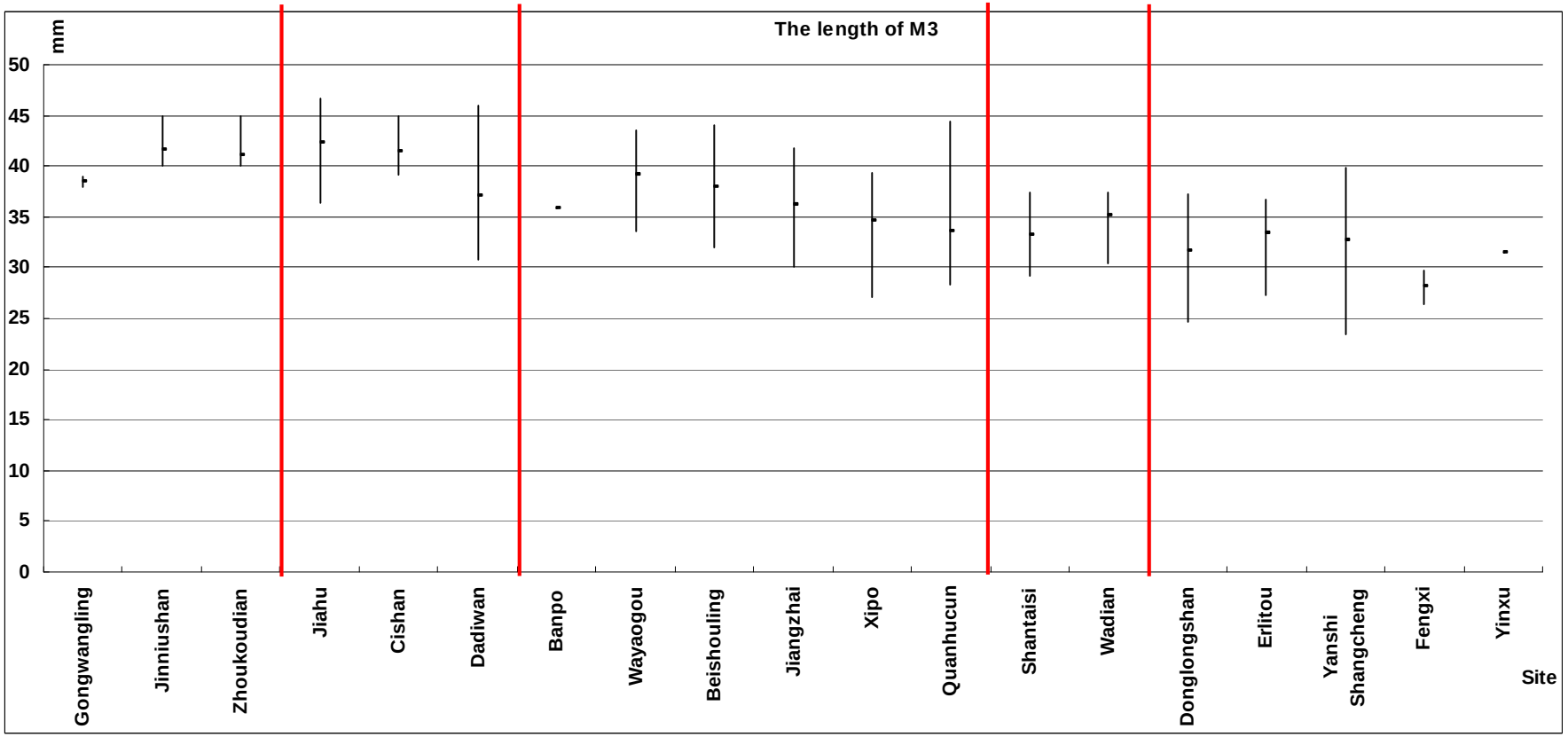


Fig. 5.4 The lengths of lower third molars of *Sus* from sites across China. From left to right, the divisions represent Paleolithic, early Neolithic, middle Neolithic, late Neolithic and Bronze Age

of M_3 from the middle and late Neolithic sites falls below 40 mm, ranging from 30 to 45 mm. During the Bronze Age, the average lengths of M_3 from all archaeological sites are below 35 mm, ranging from 25 mm to 40 mm. The reduction trend is fairly obvious and is a gradual process.

It should be pointed out that data from Dadiwan may not represent the early Neolithic period as the site lasts from 7,800 BP to 4,800 BP, lasting for about 3,000 years, although the earliest stage dates back to the early Neolithic. It has been divided into five phases. Unfortunately, studies on faunal remains were not based on stratigraphic phases and all the faunal remains were almost treated as a whole unit except for the age structure analysis for pig (Qi *et al.* 2006). Thus, we should bear this in mind when making interpretations. As indicated in Fig. 5.4, a wide range of M_3 measurements occurred at Dadiwan and, obviously, the average value of the length of M_3 at the Dadiwan site is slightly smaller than that of other early Neolithic sites, such as Jiahu, Cishan and even smaller than Wayaogou. The abnormal pattern at Dadiwan probably resulted from the fact that some data from later phases are included.

Eighteen samples for M_3 length measurements are recorded at Wayaogou. The data range from 33.5mm to 43.5mm and the average is 39.1 mm. The data of M_3 length measurements from Wayaogou fit well into the themes of the M_3 reduction trend from earlier to later periods. Also, they are quite similar to other middle Neolithic sites in the Wei River valley and slightly larger than those data from late Neolithic sites in this region.

5.3.2 Postcranial measurements: log size index

Log size index (LSI) is an effective way to increase sample sizes, when few measurable specimens are encountered (Meadow 1981) which is commonly the case for archaeological research. By using this technique, a complete skeleton of the same species is chosen as the "standard animal"; then the measurements from the whole body parts are compared with the corresponding measurements of a complete skeleton, the "standard animal". The base-10 logarithm of the measurements of the standard animal is subtracted from the log of the measurements of the archaeological specimen. These log differences can be graphed on a single axis; measurements larger than the standard animal have positive values and those smaller than the standard animal have negative values. Thus all the measurable data can be put onto a single scale by comparing them with the standard animal.

Many limitations have been proposed for such presentation methods (Meadow 1999). First, this technique is based on the assumption that the body proportions of the animals from archaeological sites were the same as, or at least similar to, the body proportions of the standard animal (Meadow 1999). But in fact, body proportions of animals vary by age, sex, region, etc. Second, body size is affected by environment and it is possible to create a false impression of size diminution by using an animal from one region to provide the standard for a more distant and environmentally different region. He also pointed out the solution to this problem is to compare the size change trend through time in one region rather than compare the exact size value on the graph when the "standard animal" from another region has been used.

"The standard animal" used in this study is a female adult wild pig from Quzhou County, Zhejiang Province (southeast China), which was hunted and produced as a modern reference specimen by Henan Provincial Institute (*Sus scrofa* NO.99 stored in Henan Provincial Institute, collected from Zhejiang Quzhou on the 17th of November, 2008). However the size variations of pigs from northern China and southern China have been noticed by scholars (Luo 2007); it is possible that the size range of wild boar from southern China is different from northern China and probably wild boar in southern China are generally smaller than those of the northern China. Since no measurement data from a complete skeleton of a pig from Northern China have been published or available to measure as the "standard animal", this female wild boar from southern China is used as the standard animal for the postcranial measurements undertaken at Wayaogou (appendix 5.3).

Considering the problems of this technique, some recommendations with respect to the use of size index have been given by Meadow (1999), for example, using only postcranial measurements and only breadth and depth measurement as they are more related to animal weight, compared to cranial measurements and postcranial length measurements. In this study, the log size index of only the breadth and depth of postcranial measurements were plotted. The phalanx measurements were excluded in this graph since the phalanges were not distinguished as fore or hind limb. The result is plotted in Fig. 5.5, which indicates that most pigs at Wayaogou were smaller than this female wild boar from southern China as most postcranial measurements fall below 0. But this pattern cannot allow us to conclude simply that most pigs from Wayaogou are domesticated individuals, since the justifications of the size variations of wild boar from

northern and southern China have not been undertaken systematically, and also "the standard animal" represents the size range of modern individuals.

A more convincing way for the analysis is to examine trends through time and to compare the index values between sites of different periods, rather than interpreting the absolute positions of the values on the size index diagrams. Thus, I use postcranial measurement data from another two sites in the Wei River valley, the Lingkou site and the Quanhucun site for comparison. Since systematic measurement data were not available from the faunal reports of these two sites, all postcranial bones stored in the research base of Shaanxi Provincial Institute were measured during my field work in the summer of 2009, with the permit of the directors, following the standards set by von den Driesch (1976). The time periods of the archaeological remains at Lingkou are quite controversial and the general acknowledgement is that the site is no later than the early phase of middle Neolithic. The metric data of Quanhucun were mainly from the middle phase of the Yangshao period, which is later than Wayaogou.

Using the same standard animal (Henan Provincial Institute S*us scrofa* No. 99), log size indices for pig bones from Lingkou and Quanhucun are compared with those from Wayaogou, as shown in Fig. 5.6. The differences of size index values between the Wayaogou and Lingkou and Quanhucun assemblages are worth noticing. First, LSI has a relatively small range at Wayaogou compared to those at Lingkou and Quanhucun, which coincides with the chronological information, based on the pottery typology, that occupation at Wayaogou lasted a relatively short time. Second, the graph suggests that there is a general reduction trend of

log size index from the early to late periods in this region. Thus, the size reduction trend of pigs over time can be inferred from this study.

5.4 Age Profiles

Cull pattern is one of the most frequently used methods to document the domesticated status of animals from archaeological sites. It is based on the assumption that the domesticated populations were slaughtered at ages different from wild populations. Cull pattern is mainly investigated by examining the state of epiphyseal fusion and tooth eruption and wear stages of a population. In this section, cull pattern for pigs from Wayaogou will be investigated based on the studies of fusion data and mandible wear stage data.

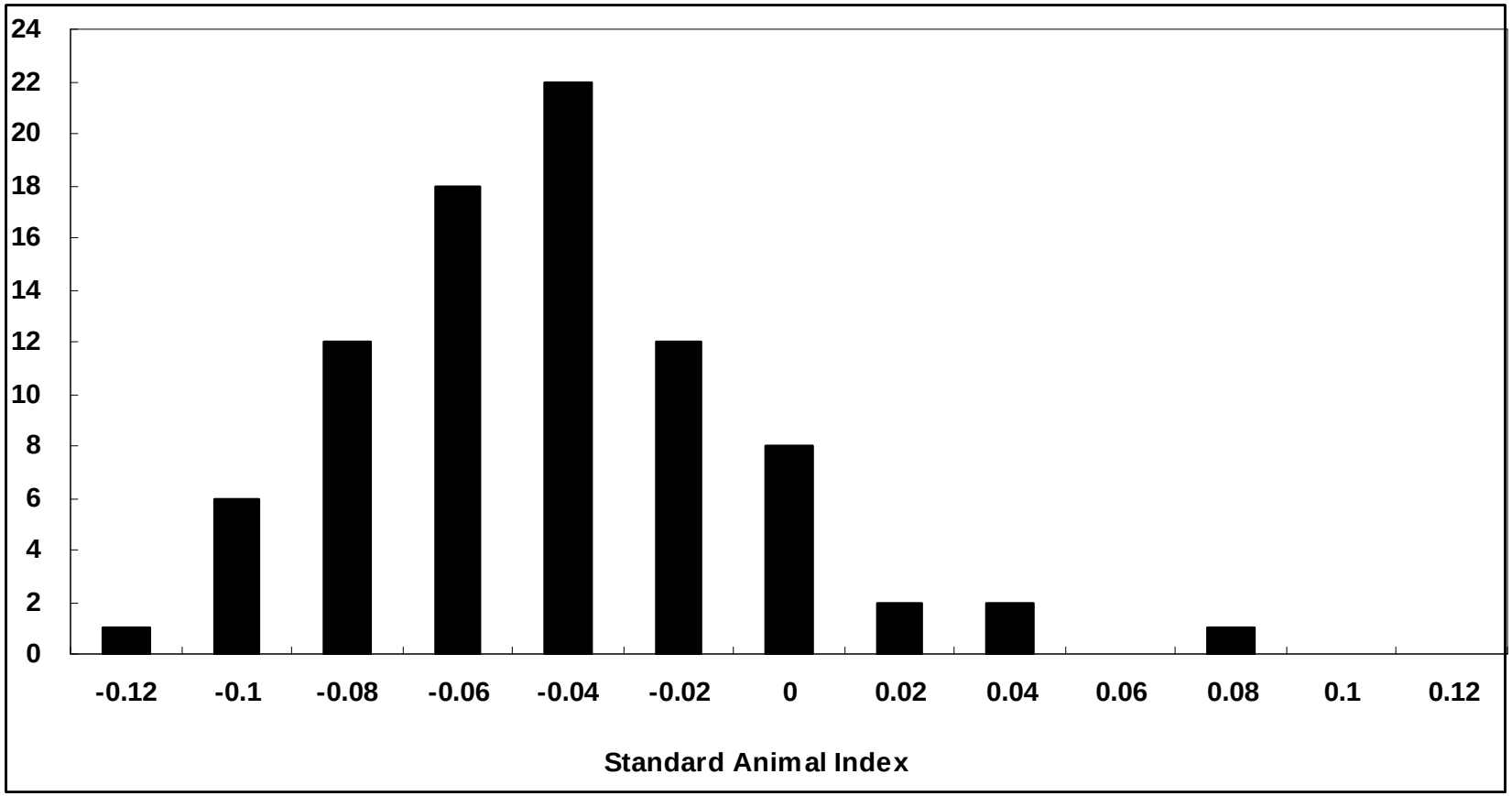


Fig. 5.5 Standard animal values (see text for explanation) for pig postcranial bones at Wayaogou (N=84)

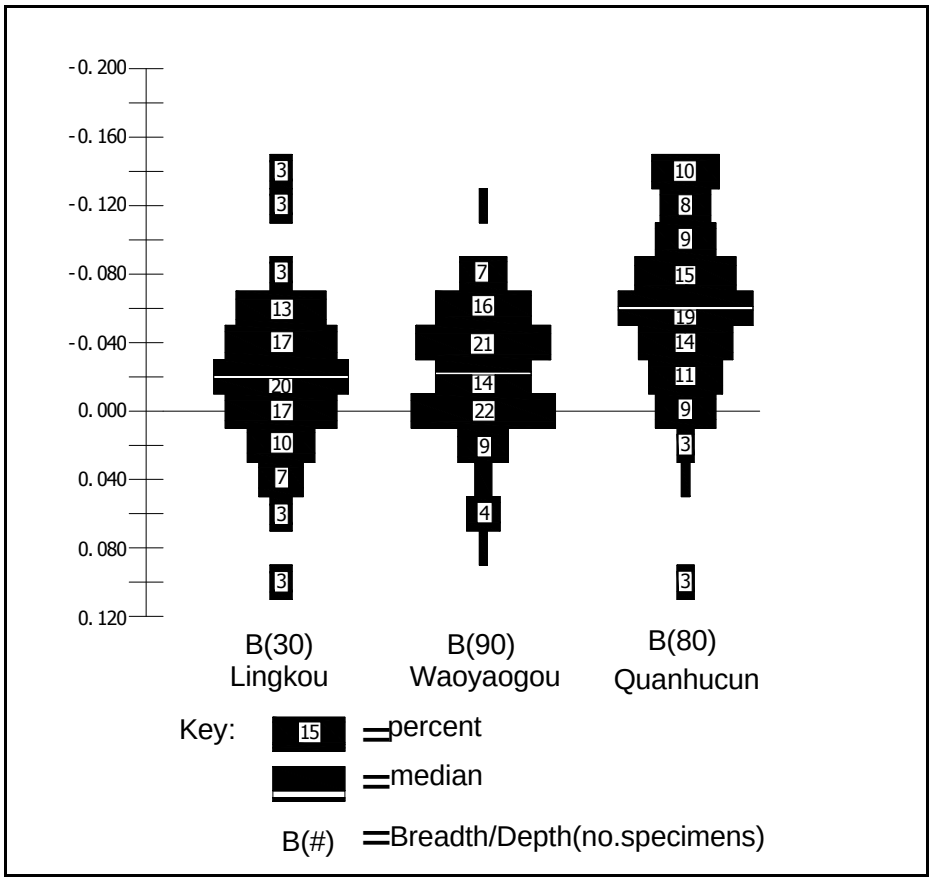


Fig. 5.6 Summary of log size index data for pig from Wayaogou, Lingkou and Quanhucun. The median values are also plotted

5.4.1 Fusion ageing

The epiphyseal fusion of different body parts occurs at different stage during an animal's life and the epiphyseal fusion status (unfused, fusing and fused) provide clues for animal ageing. Although serious flaws with fusion ageing methods have been pointed out by researchers (Watson 1978), it is still a worth trying way to detect the slaughtering pattern of animals from archaeological sites.

Post-cranial parts for the pig can be put into three groups (Tab. 5.1), according to the sequence of fusion presented by Silver (1969) and Bull and Payne (1982). In general, epiphyses of scapula, pelvis, distal humerus, proximal radius and

proximal end of the second phalanx fuse at stage I, which is before 12 months, representing infantile and juvenile animals; the epiphyses of many elements, including distal metacarpals, distal metatarsal and distal tibia and fibula, fuse at stage II, between 24 and 30 months, representing subadult animals; late fusion body parts includes epiphyses of proximal humerus, proximal and distal ends of ulna, femur, and proximal tibia; these epiphyses fuse at stage III, between 36 and 42 months, representing adult animals.

Tab. 5.1 shows the survivorship for pig based on epiphyseal fusion for pig skeletal parts at Wayaogou, indicating that about 76% of pigs at Wayaogou survived more than 12 months, which means about 24% died before they reached 1 year old. Survival rate at stage II is still high at 62%. Survival rate at stage III is about 30%, suggesting that kill-off took place mainly during the subadult age (24-36 months). Fig. 5.7 shows the survivorship curves for pigs from Wayaogou. Unfortunately, comparative data for fusion ageing were not available from sites in the Wei River valley; results from the Xipo site (Ma 2007), a Yangshao period site in Henan Province (Central Plain) are plotted in the same graph for comparison. An earlier kill-off schedule was observed at the site of Xipo (5,800-5,300 BP, Henan Province) compared with Wayaogou, with 80% killed before 24 months.

Stages	Epiphyses	Fusion age (months)	Number fused	Number unfused	Number fusing	% unfused	%fused survivorship
I	Scapula	**12**	32	6	1	15.38%	
	Pelvis	**12**	38	9	1	18.75%	
	Humerus d	**12**	52	37	23	33.04%	
	Radius p	**12**	33	3	0	8.33%	
	Phalanx 2 p	**12**	21	8	3	25.00%	
	TOT	**12**	**176**	**63**	**28**	**23.60%**	**76.40%**
II	Metacarpus2 d	**24**	0	0	1	0.00%	
	Metacarpus3 d	**24**	4	4	1	44.44%	
	Metacarpus4 d	**24**	2	2	0	50.00%	
	Metacarpus5 d	**24**	2	1	0	33.33%	
	Metacarpus d	**24**	2	1	0	33.33%	
	Tibia d	**24**	34	23	4	37.70%	
	Fibula d	**30**	1	1	0	50.00%	
	Metatarsal2 d	**27**	1	2	0	66.67%	
	Metatarsal3 d	**27**	5	0	1	0.00%	
	Metatarsal4 d	**27**	5	0	1	0.00%	
	Metatarsal5 d	**27**	9	0	3	0.00%	
	Metatarsal d	**27**	2	0	0	0.00%	
	Calcaneum	**24-30**	8	22	4	64.71%	
	Metapodia d	**24**	17	9	3	31.03%	
	Phalanx 1 p	**24**	1	2	0	66.67%	
	TOT	**24-30**	**93**	**67**	**18**	**37.64%**	**62.36%**
III	Humerus p	**42**	4	12	1	70.59%	
	Radius d	**42**	5	19	0	79.17%	
	Ulna p	**36-42**	7	12	2	57.14%	
	Ulna d	**36-42**	0	6	1	85.71%	
	Femur p	**42**	5	17	3	68.00%	
	Femur d	**42**	2	19	5	73.08%	
	Tibia p	**42**	6	27	7	67.50%	
	Fibula p	**42**	0	1	0	100.00%	
	TOT	**36-42**	**29**	**113**	**19**	**70.19%**	**29.81%**

Tab. 5.1 Survivorship for pig based on epiphyseal fusion of skeletal parts at Wayaogou; Allocation for the different epiphyseal fusion stages based on Silver (1969) and Bull and Payne (1982)

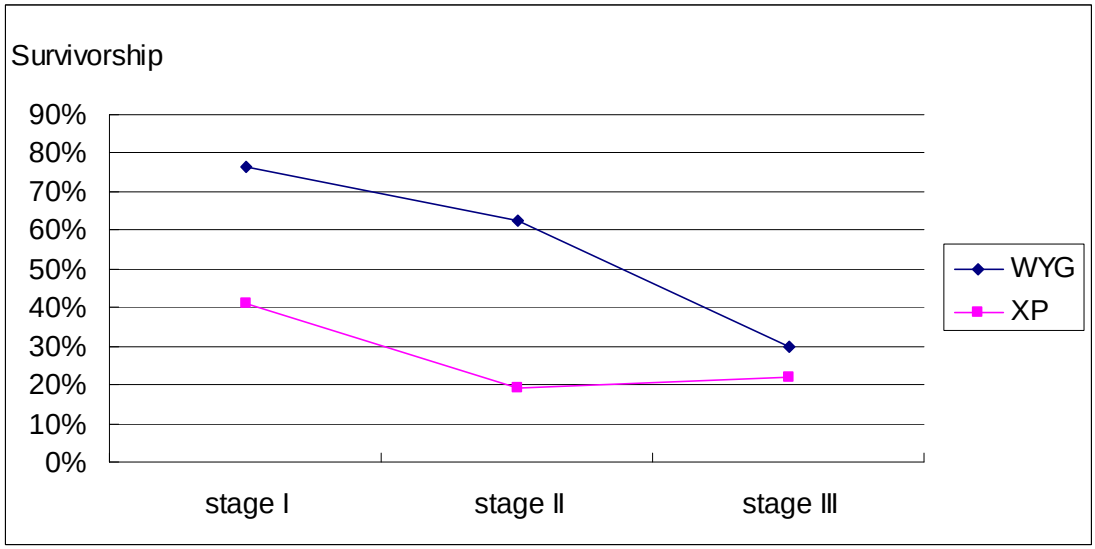


Fig. 5.7 Survivorship curves for pig based on epiphyseal fusion for Wayaogou, compared with the Xipo site (5,800-5,300 BP)

5.4.2 Dental ageing

Tooth eruption sequences and wear stages seem to be reliable for investigating the slaughter patterns of animals. Grant (1975, 1982) presented an effective way to record the tooth wear eruption and wear stages. Different stages of eruption and a set of tooth wear stages were recorded using codes (Fig. 5.8). A mandible wear stage is calculated by adding the scores assigned to each molar according to its stage of eruption and attrition. Also, Grant provided some patterns of mandible wear stages (M.W.S.) based on the observation of pig remains from archaeological sites in Britain, ranging from the Bronze Age to the eighteenth century. She assumed that the wear patterns of those mandibles with missing molars could be predicted by comparison to data she had provided. But the problem is that her study is restricted to a certain geographic region and mainly to historical periods, which mean those data may have limited application.

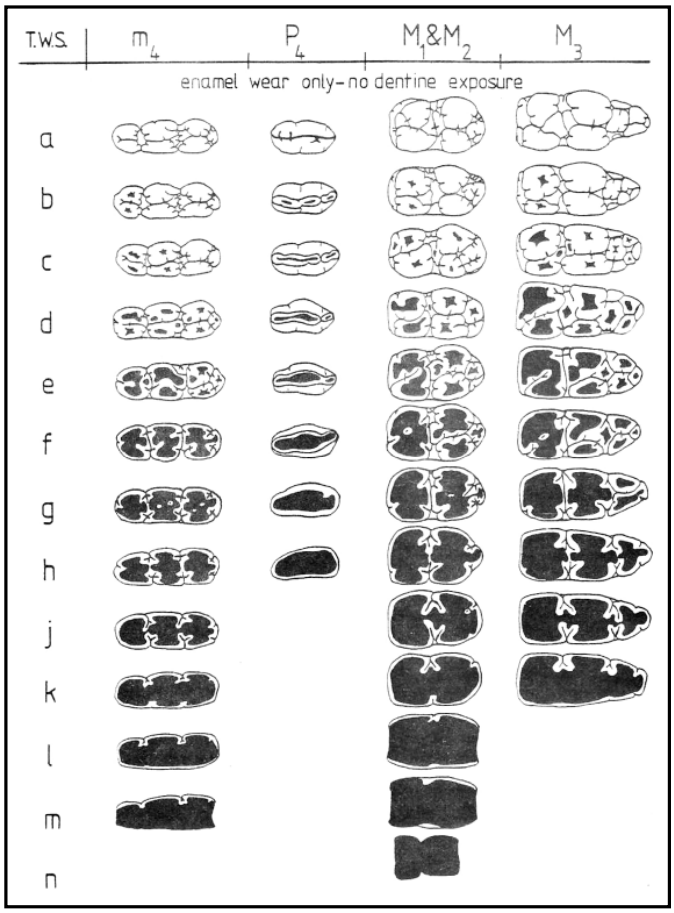


Fig. 5.8 Code for recording pig tooth wear stages (after Grant 1982)

Patterns of molar wear stages from Wayaogou and an early Bronze Age site (Donglongshan) in the Wei River valley are tested by comparison to those provided by Grant. It has been indicated that the M.W.S. patterns of Wayaogou and Donglongshan are quite different from those observed by Grant. It seems that, with the first molar at any given stage of attrition, the normal range of wear on associated second molars is comparatively advanced among Wayaogou pig. Analogous patterns are documented for associated second and third molars, with comparatively heavy wear on the third molars among Wayaogou pigs. Those patterns seem consistent with pig mandible data from the Marquesan Islands (Rolett and Chiu 1994)). It also has been proposed by Ma (2007) that there is a

delayed eruption for M_3 at Xipo site (middle Neolithic, 5,800-5,300 BP) in central China, which is less obvious at Wayaogou probably due to the relatively small assemblage of young pigs. Since complete tooth rows are relatively scarce at Wayaogou, it is not applicable to predict wear stages of the missing teeth for the two tooth rows.

Hongo and Meadow (2000) developed an effective method to age pigs from archaeological sites, based on the tooth wear stages defined by Grant (1975, 1982) and Bull and Payne (1982). First, the tooth eruption and wear stages were recorded according to Grant's graph and codes (1982). Then, loose teeth and tooth rows were classified into six age stages, representing different stages of pig life (Hongo and Meadow 2000) (Tab. 5.2). The first three stages represent infantile and juvenile animals (up to ca. 12 months), stage IV and V subadult (ca. 12 to 18 months and ca. 18 to 24 months, respectively), stage VI full adult (ca. 24 to 36 months) and VII old animal (over ca. 36 months).

In the case of Wayaogou, 183 mandibles were recovered, including 45 specimens with complete molar rows and 41 specimens with two molars present, all these specimens were recorded during the field work (appendix 5.4). The eruption and wear stages of these mandibular teeth, including both left and right, were recorded according to Grant's system and each tooth present was assigned to one of the T.W.S, illustrated in the graph (Fig. 5.8). As mentioned above, the method of calculating the numerical values of each mandible to observe the age structure seems not to be applicable to Wayaogou due to small sample size. Thus, in the following step, tooth wear stages defined by Hongo and Meadow (2000) were

applied to determine the exact ages of pig remains from Wayaogou; this is quite straightforward way to investigated pig cull pattern.

The results are plotted in Fig. 5.9, suggesting that most pigs at Wayaogou were killed between 6 to 24 months when they were juvenile or subadults. The age profile falls well into a pattern of a domesticated population, with few very young and few very old animals. This supports the domesticated status of pigs inferred from metric data. And also, the relatively high percentage of juvenile and subadults suggests that pigs were mainly exploited for meat since most of them were killed when they reached their maximal body weight.

The limitation of tooth ageing is that the eruption and wear of mandibular teeth could be affected by different factors. Environment, diet, breeding and sex may all potentially alter the rate of eruption and wear (Grant 1978, 1982: 105). There are different opinions among scholars regarding the timing of tooth eruption in wild and domestic, as well as in modern and ancient pig populations, summarized by Bull and Payne (1982). It has been suggested that data for slower-erupting modern pigs or for wild boar are probably most suitable for general application to teeth and jaws from archaeological sites. Considering these problems, the best way to interpret results is to use the relative age stage as the primary units of analysis, rather than absolute ages (Hongo 1996).

The tooth wear patterns from Wayaogou are compared to Xipo (5,800-5,300 BP, Henan Province) (Ma 2007) and Donglongshan, to investigate variations between different regions through times (Fig. 5.9). Donglongshan is an early Bronze Age

site in Shaanxi Province; tooth wear data for pig were collected during my 2008 season field work. In general, the age structure pattern of pigs at Wayaogou is quite similar to that of Xipo, and most pigs were killed as juvenile and sub-adult, before two years old. But there is a slight difference between them: it seems that there is a longer life span for pigs at Wayaogou as more than 20% were killed between 18 and 24 months, whereas only about 12% are represented at Xipo; a high percentage of newborn pigs died at Xipo (21.8%), compared to about 13% at Wayaogou. This difference indicates different husbandry practices at those two sites, probably resulting from different social cultural choices.

Also, a comparison has been made between the sites of Wayaogou and Donglongshan in Shaanxi Province (Fig. 5.9). Data from Donglongshan site have been analyzed using the same method defined by Grant (1982) and Hongo and Meadow (2000). Most pigs at Donglongshan were slaughtered before they are 12 months old. So an earlier kill-off schedule pattern can be proposed for pigs from Donglongshan compared to those from Wayaogou.

Cull patterns observed from tooth eruption and wear are different from those generated from fusion data, at both Wayaogou and Xipo. The fusion data indicate a later kill-off schedule at both sites compared with tooth ageing. As was demonstrated, there are many serious flaws in the interpretation of epiphyseal fusion data (Watson 1978). The most serious one is differential destruction of unfused specimens relative to fused ones. Another factor is that fusion ages vary from breed to breed. Also, the recovery bias in unsieved samples could affect the

Wear Stages	**Ages**	**Tooth wear stages (a-n) (after Grant 1982)**									
		dp_4	**dp other**	**D_i**	**M_1**	**I_1**	**I_2**	**P_2, P_3, n.d. P**	**P_4**	**M_2**	**M_3**
1	Newborn	a b c	erupting slight	erupting slight							
2 (M_1 erupting)	up to ca. 6 months	d	moderate		erupting a, b						
3 (M_2 erupting)	ca. 6-12 months	e, f, g, h, i, j, k, l	moderate heavy	moderate heavy	c,d,e					erupting a, b	unerupted
4 (P_4 erupting)	ca. 12-18 months					erupting		erupting, slight	a, b, c		
5 (M_3 erupting)	ca. 18-24 months				f, g, h		erupting	moderate	d, e	c, d, e	a, b
6	ca. 24-36 months				j, k	heavy	heavy	heavy	f	f, g, h	c, d, e
7	Over 36 months				l, m, n				g, h	j, k	f, g, h, i, j

Tab. 5.2 Tooth eruption and wear stages for pig; reproduced from Hongo and Meadow (2000)

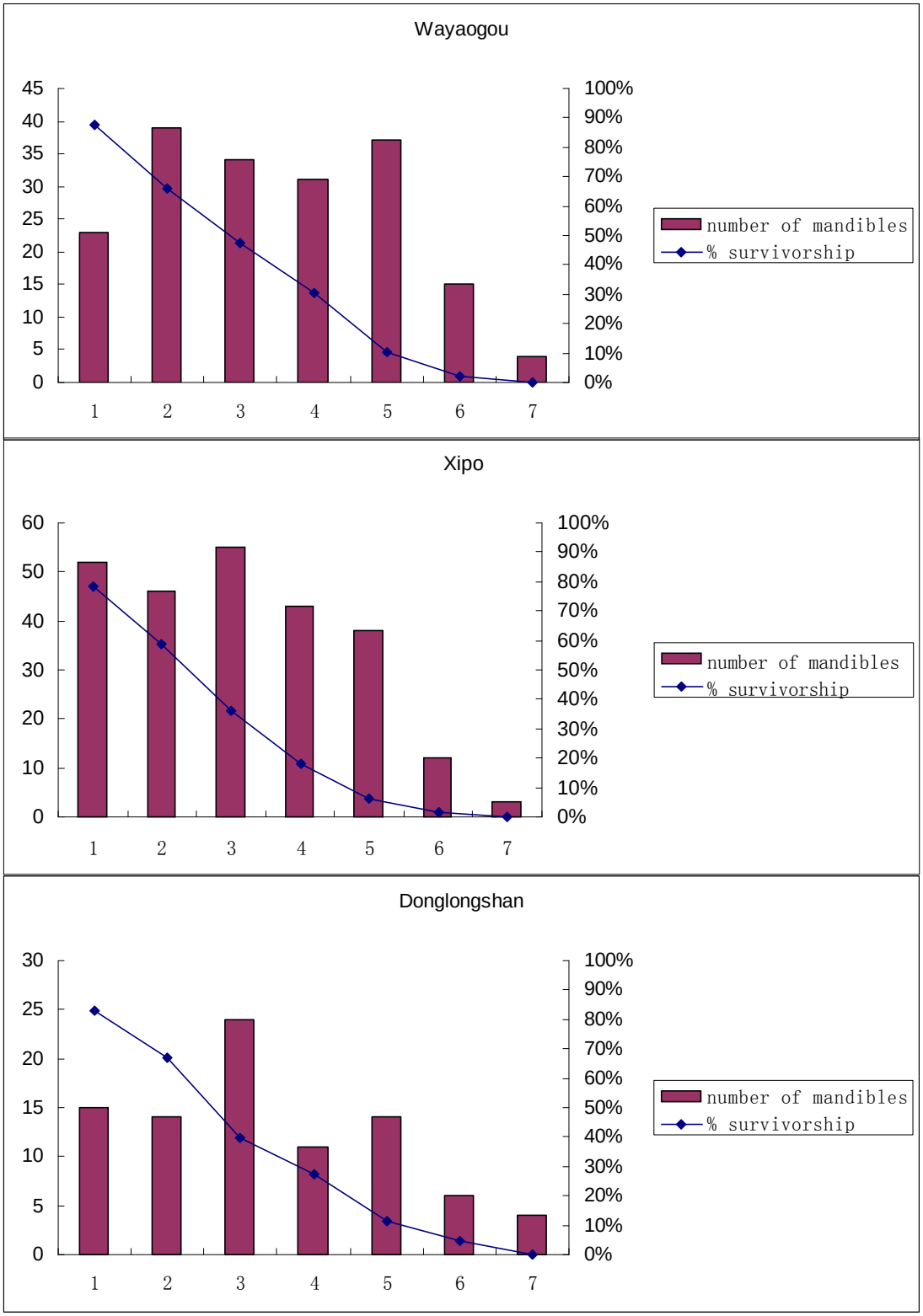


Fig. 5.9 Kill-off patterns for pig from Wayaogou, Xipo (5,800-5,300 BP) and Donglongshan (4,000-3,000 BP) based on tooth eruption and wear

frequency of unfused specimens and fused ones. Unfused specimens suffer higher destruction and more chance of being overlooked with hand picking, and they have less chance to be present at sites, compared to fused ones. Thus, with the retrieval bias towards fused specimens, a relative later slaughter schedule may be inferred from fusion data. Considering these factors, it seems that fusion ageing is less reliable compared to dental ageing and tooth eruption data, which can be used for ageing with greater confidence in this study.

5.5 Seasonality of pig slaughtering based on mandible wear stages

It has been proposed that the detailed recording of tooth eruption and wear could shed light on the seasonal slaughtering pattern in pig populations (Ervynck 1997, 2005, following Grant 1982). By comparing figurative schemes, Grant defined 52 separate mandible wear stages, which has a great advantage over other methods with fewer age groups. Based on the assumption that pigs were born seasonally, usually in spring, the distribution of mandible wear stages (MWS) values showing clear peaks and troughs could be the result of seasonal slaughtering (Fig. 5.10). This method has been applied to some medieval sites in Belgium (Ervynck 1997), and convincing seasonal slaughtering patterns have been interpreted.

Systematic recording of tooth eruption and wear stages has been undertaken for the sites of Wayaogou and also Quanhucun, making it possible to apply this method to these two sites to assess whether it produces results at Chinese Neolithic sites. Fortunately, large quantities of mandibles were recovered from the sites, making it theoretically possible to use the method to detect seasonal slaughtering patterns. Only mandibles with complete tooth rows were used to

produce MWS estimates. The frequency distributions of each wear stage are plotted in Fig. 5.11a and Fig. 5.11b for Wayaogou and Quanhucun. These show that there are clear peaks and troughs in the frequency distribution of MWS at Wayaogou. In general, the first peak can be noticed at MWS 4-5 and the second peak at MWS 13 and 14, followed by MWS 22 and MWS 28; there is a less pronounced peak for old individuals (MWS 46). The frequency distributions of MWS at Quanhucun also show clear peaks and troughs. In general, the first peak can be observed at MWS 2, followed by the second peak at MWS 10, a third peak at MWS 18 and the fourth at MWS 28. It seems that the distribution of age classes at Wayaogou and Quanhucun are quite similar to the theoretical pattern (Fig. 5.10) proposed by Ervynck (1997). Based on this, winter slaughtering could be proposed, with the first peak representing a high mortality rate during birth and the second peak representing slaughtering in the first winter, the third peak killings in the second winter, and the fourth peak slaughtering during the fourth winter. The peaks and troughs at both sites show unequal distributions on the graph, which could be the result of many factors, for example, mass slaughtering may happened at different months at different sites, tooth wear rates may vary at the sites due to food abundance and there may be genetic differences in wear rates.

As mentioned above, compared to the patterns observed by Grant (1982), there is advanced wear for the M_2 and M_3 compared to the associated M_1 in the Wayaogou pig population. A similar pattern can also be observed for Quanhucun. Many factors can influence the variation of pig tooth eruption and wear patterns, such as genetic variation and diet difference. It is possible pigs in different areas were fed

differently, and the food has different abrasion rates for the teeth.

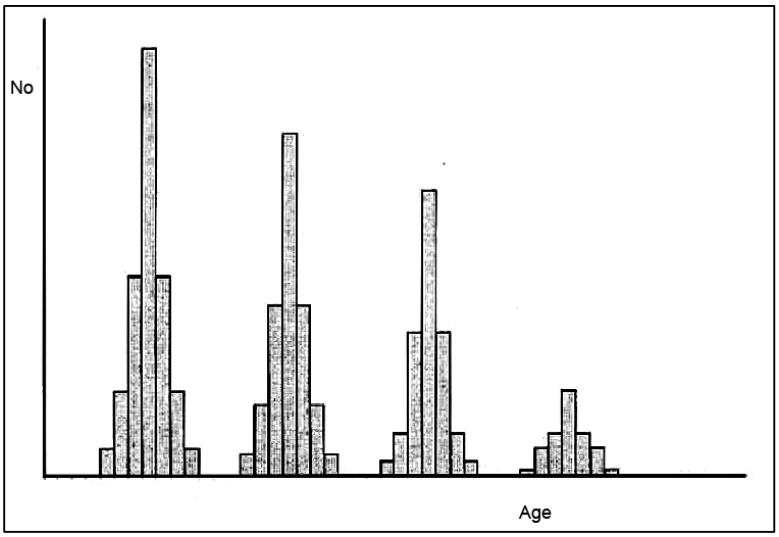


Fig. 5.10 Example of a theoretical distribution of age classes for single farrowing pig population, derived from a cohort of animals born in the same season and all slaughtered in a limited period within the year. The peaks represent animals killed during the first, second, third and fourth winters (from Ervynck 1997: 69).

Criticisms that might be raised against interpreting peaks and troughs as seasonal slaughtering include the possibility that they result from unequal time lengths being represented by wear stages rather than actual differences in the frequencies of slaughtering per MWS. It is possible that troughs in the distribution simply consist of shorter wear stages, taking little time for the animal to go through. O'Connor (2003) remarks that it is conceivable that teeth go through their first tooth-wear stage class rather quickly (during eruption and early wear) while it takes considerably more time to proceed from one later stage to another when a tooth is completely erupted and already fully in wear. He argues that this pattern

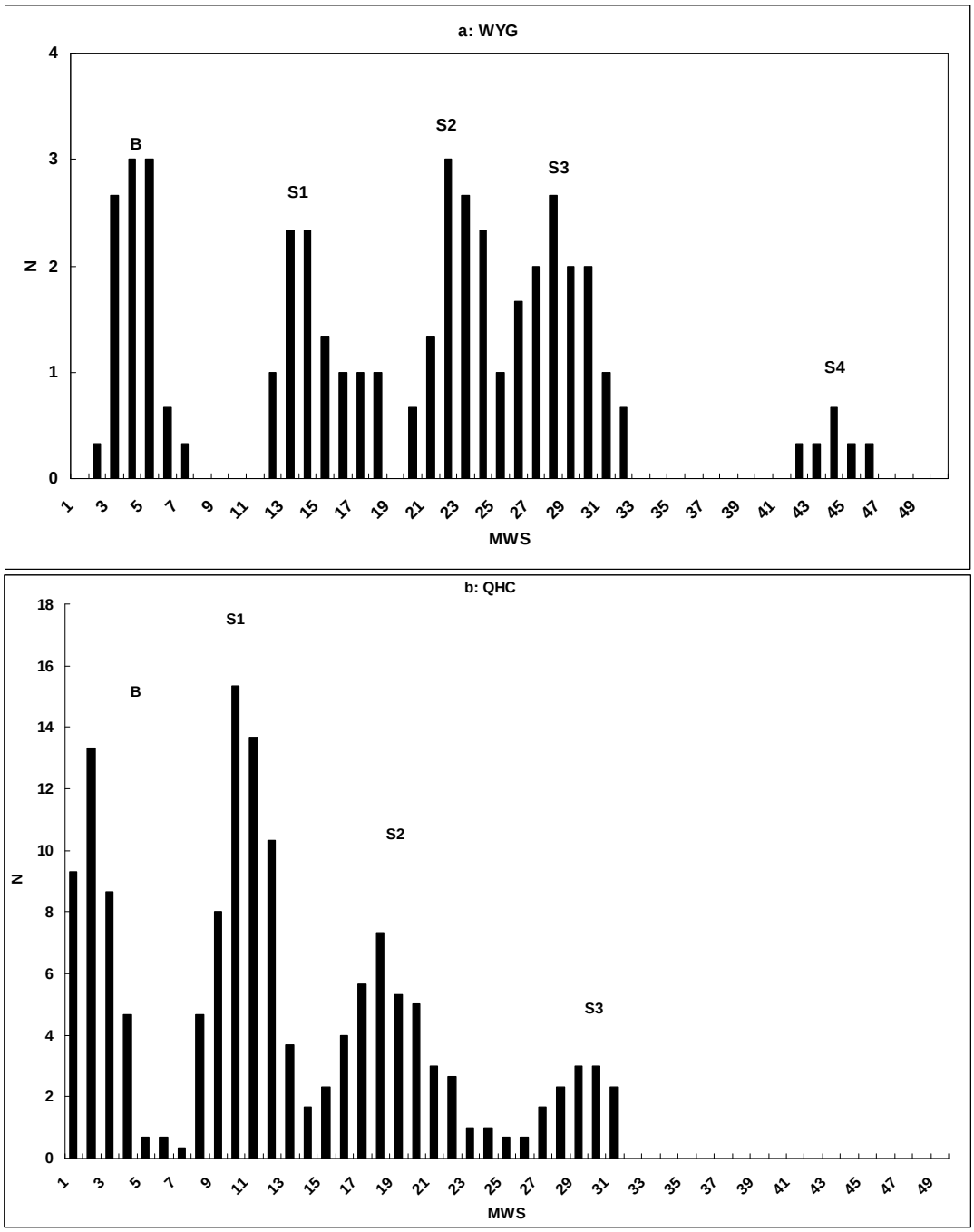


Fig. 5.11 Mandible Wear Stage (MWS) distribution for pigs from Wayaogou (N=45) and Quanhucun (N=152); Class values are expressed as running means, with a factor n=1

could produce peaks and troughs in the MWS distribution. Moran and O'Connor (1994) observed such stand-stills in the molars of recent sheep, but this would not

occur in pig. Detailed studies suggest that troughs observed in the distributions would only reflect uneven time lengths of MWS classes if teeth wear fast together, whilst peaks would occur if only teeth “stand still” simultaneously. Since there is a large overlap between the “slowing down” of one tooth and the eruption and early wear of the following ones, it is reasonable to argue the troughs and peaks in the distribution can best be related to seasonal killing.

Fig. 5.11 suggests that there are clear patterns for the mandible wear stages (MWS) at Wayaogou and Quanhucun, with five peaks observed at Wayaogou and four at Quanhucun. Seasonal slaughtering patterns can be clearly observed at these two sites. However, there are some differences in the timing of the peaks between the two sites. It seems that pigs were killed at a slightly later stage for the first three peaks at Wayaogou than those at Quanhucun. There are two possible explanations for this: first, teeth may wear at different rates at the two sites due to the quality and abrasive properties of their food. Different pig feeding may well have been used since these animals make up very different proportions at each site (38% at Wayaogou & 80% at Quanhucun). It is possible that pigs enjoyed better feeding conditions at Wayaogou as there is relatively lower frequency of pig bones, which may indicate pigs were less populated at Wayaogou than that at Quanhucun. At Wayaogou, it can be observed from the raw data list that when the M_1 erupts the MWS is 3-4, when the M_2 erupts the MWS is 13-14 and when the M_3 erupts the MWS is 23-25. When it comes to Quanhucun, the raw data list suggests that when the M_1 erupts the MWS is 2-3, when the M_2 erupts the MWS 8-11 and when the M_3 erupts the MWS is 19-21. It is obvious that there is a slight difference in the tooth eruption and wear between the two sites. Thus, differences in teeth eruption

and wear rate could be one factor that causes different patterns of the peaks and troughs in MWS.

The second explanation could be that different husbandry strategies may have been practiced at the sites, which means pigs may actually have been killed in different months of the year at the two sites. This is quite possible because as we have seen pigs played a less important role in the subsistence system at Wayaogou (38% of faunal remains) than that at Quanhucun (80% of faunal remains). Hence, the proposition could be that although seasonal slaughtering did occur at Wayaogou and Quanhucun, there are differences in the timing of mass killing between the two sites. If pigs were born in spring (March or April), they would have been 8 months old when entering their first winter (MWS 9-11). At the second winter, they would have been about 20 months old (MWS 19-21). Fig. 5.11 shows that the second peak of MWS at Quanhucun comes at MWS 9-11 and the third one comes at MWS 19-21, which means mass killing occurred when the animals were about 8 months (the first winter) or 20 months old (the second winter). Thus, a winter slaughtering pattern is quite clear at Quanhucun. When it comes to Wayaogou, Fig. 5.11 suggests that many pigs were killed at MWS 13-16 and 22-25. If the pigs were born in spring, they would have been almost 10-11 months old when the first mass killing occurred, probably in early spring. The third peak of MWS suggests that many pigs were killed when they were about 20 months old, probably during the early spring. Thus, it seems that spring slaughtering pattern was the pattern at Wayaogou.

A winter slaughtering pattern is fairly clear at Quanhucun and has been proposed

for some medieval sites in Europe (Ervynck 1997). In China, most domestic pigs give birth in spring and are slaughtered in winter to celebrate the Chinese New Year (annually in February) in remote areas today. Winter slaughtering is quite common therefore for pig populations, but does not seem to be the case for Wayaogou, where spring slaughtering is interpreted. Early spring is another lean season in terms of the availability of plant resources since most plants can not be used for subsistence. Different patterns in timing of mass killing may relate to the different roles that pigs played in the subsistence system at Wayaogou and Quanhucun. Pigs comprised of about 80% of faunal remains at Quanhucun which indicates they were the main meat resource for humans while hunting played a minor role in the subsistence system. In this circumstance, it was wise decision to undertake mass killing in winter, as it is possible to store the meat or preserve it as ham since the temperatures could be very low in winter. Also, pigs can be very competitive with human in terms of food requirements during winters at Quanhucun because of their large numbers. At Wayaogou, pig bones made up only about 38% of faunal remains and deer about 56%, indicating that hunting played an important role in subsistence. Pig, as the main domestic animals at Wayaogou, could be the reliable subsistence resource for humans during the lean season. Early spring could be the leanest season for human as stored food from the previous year may have been consumed, and other resources not yet available.

Double farrowing of pigs is quite common in both modern times and in the historic period. Studies suggest that it is possible for wild boar to deliver two litters a year when food is plentiful. Thus, the possibility of the domesticated sow being served throughout the year, and the possibility of having more than one

farrowing a year, is not characteristics of domestication but rather a natural characteristic of the species *Sus scrofa* (Lauwerier 1983).

Two methods will be used here to detect second farrowing in this paper: first, mandible wear stages (MWS), which have been used to trace pig seasonality, could provide evidence of second litters if they were born at the sites; second, linear enamel hypoplasia will provide more detail about animal life cycles.

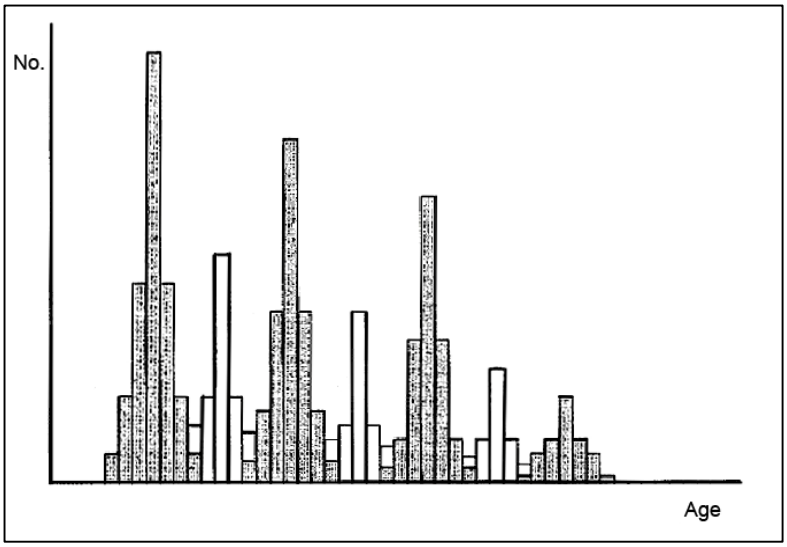


Fig. 5.12 Example of a theoretical distribution of age classes for double farrowing pig population, derived from a cohort of animals born in two seasons (shaded and white) and all slaughtered in a limited period within the year (from Ervynck 1997)

A theoretical distribution of age classes of a pig population with second farrowing has been proposed by Ervynck (1997). Assuming a spring and autumn farrowing, a traditional slaughtering period in winter will produce a double number of peaks in the MWS distribution curve (Fig. 5.12). As mentioned above, if seasonal killing is exercised upon a pig population, the distributions of the MWS-values should

show discrete peaks. In the case of a single seasonal killing period, the distance between the peaks should represent the time span of one year. In the case of a second farrowing and a single killing season, the distributions should show double the number of peaks, which must then be at distances representing half a year. Following these theoretical assumptions, there seems no clear evidence suggesting the presence of second farrowing at Wayaogou (Fig. 5.11a). The distance between the peaks roughly represents one year at the site and the mandible wear stages are quite consistent with a theoretical model of a single farrowing (Fig. 5.10). Similar patterns can be observed at Quanhucun (Fig. 5.11b). Recent research suggests that the reproduction of wild pig population in Henan Province usually occurs once a year, usually in the April and May (Ma 2010).

Although there are certainly methodological problems involved in the evaluation of distributions of MWS values, this does not mean that the method should not be attempted. More case studies need to be evaluated before final conclusions can be drawn. Experiments wherein tooth eruption and wear are followed over years in large groups of living animals will shed significantly more light on the methodological problems discussed above.

Many factors could influence the application of the method, such as variation in the timing of birth and slaughtering, and differences in tooth eruption and wear, caused by food abundance, genetic variation or environmental conditions. The methods used here have seen some criticism, but case studies show that they have worked well for some medieval sites in Europe and the methods have fewer inherent problems for domestic pigs than for sheep or cattle.

5.6 Linear enamel hypoplasia analysis

5.6.1 Materials and samples

Linear Enamel Hypoplasia (LEH) is a deficiency present on the enamel of human or animal teeth and it occurs during tooth crown formation, typically visible on a tooth's surface as one or more lines or depressions (Colyer 1988) (Fig. 5.13). LEH has been widely used in some European sites to trace pig domestication and husbandry strategies, but has seldom been applied in China. In order to have a comprehensive basis for comparison, the occurrence of LEH in this research was recorded on pig teeth both not only from Wayaogou (appendix 5.5), but also from another three sites in the Wei River valley: Lingkou (early phase of the middle Neolithic, 7,500 BP), Quanhucun (late phase of the middle Neolithic, 6,000 BP) and Donglongshan (early Bronze Age, 4,000 BP). Pig remains are all well preserved at these sites. At Quanhucun and Donglongshan, pig bones make up more than 80% of the faunal remains. Preliminary assessment suggests that pigs show high frequency of LEH occurrence at all these sites. As mentioned in the methodology chapter (3), only mandibular teeth were used in this study and mandibles are selected for recording if one or more molars were present.

The inventory of the material studied is represented in Tab. 5.3. It shows that all tooth types were abundant in the study collections and from each site a large number of teeth were available.

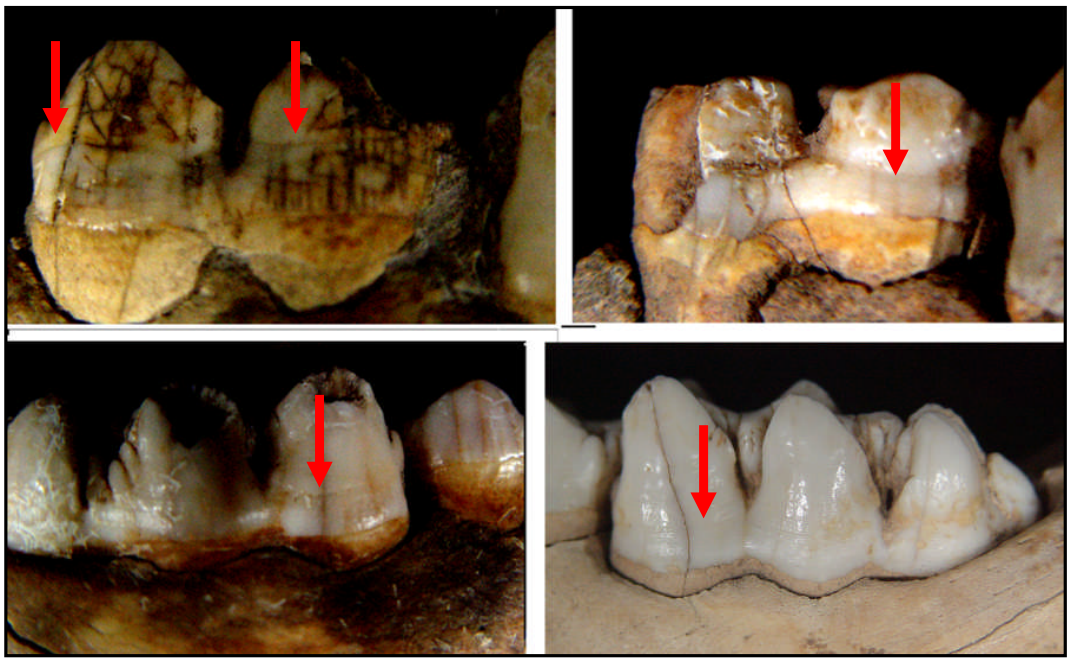


Fig. 5.13 Linear enamel hypoplasia (arrowed) on the lingual surface of mandibular second and third molars of pigs from Wayaogou

Site	No. Mandibles	M_1	M_2	M_3	Total No. of teeth
LK (Lingkou)	47	15	22	34	71
WYG (Wayaogou)	72	39	34	31	104
QHC (Quanhucun)	232	129	70	18	217
DLS (Donglongshan)	57	37	30	13	80
All sites	408	220	156	96	472

Tab. 5.3: Inventory of pig dental material studied for all sites

5.6.2 Result 1: Presence and frequency of LEH

The number and frequency of LEH occurrence on each cusp of each molar is listed in Tab. 5.4, which suggests that LEH is a common phenomenon in the pig populations investigated, although the frequencies vary and some teeth show higher frequencies of LEH than others. One problem with LEH analysis is that

wear stages could have a direct influence on the presence of LEH on some teeth. Populations with many young individuals (e.g., with only the M_1 erupted) have a less chance of showing LEH on the M_2 and the M_3 compared to populations with many older animals (with all teeth erupted). And also, there is less chance for the M_1 to show LEH in populations with many old animals as those LEH episodes could have been worn away. In order to enable the simultaneous evaluation of all observation when comparing the occurrence of LEH between sites, an index was developed which adjusted the data to measure the deviation of each sample from the pooled data from all samples (Ervynck and Dobney 1999). For each site, this adjustment was obtained by dividing the average number of LEH lines per tooth and cusp by the average number of LEH lines for all sites combined. This calculation enables the comparison of the average relative frequency of LEH for an individual site with the one calculated for all sites. The standard deviation of the calculated average, per site, describes the variation between teeth and cusps within that site.

Site		M_1a	M_1p	M_2a	M_2p	M_3a	M_3m	M_3p
	No. of LEH	0	1	10	9	26	16	3
	No. of cusps observed	14	15	21	22	34	23	4
LK	**Frequency**	**0**	**0.07**	**0.48**	**0.41**	**0.76**	**0.7**	**0.75**
	No. of LEH	7	5	9	14	24	15	2
	No. of cusp observed	39	37	32	34	31	25	18
WYG	**Frequency**	**0.18**	**0.14**	**0.28**	**0.41**	**0.77**	**0.60**	**0.01**
	No. of LEH	47	33	37	31	14	4	0
	No. of cusp observed	129	117	70	67	18	16	1
QHC	**Frequency**	**0.36**	**0.28**	**0.53**	**0.47**	**0.78**	**0.25**	**0**
	No. of LEH	17	15	17	11	9	3	1
	No. of cusp observed	35	37	30	23	13	5	5
DLS	**Frequency**	**0.49**	**0.41**	**0.57**	**0.48**	**0.69**	**0.6**	**0.2**

Tab. 5.4 Frequency of Linear Enamel Hypoplasia (LEH) episodes recorded per tooth cusp (for the number of specimen); (for site codes see Tab. 5.3)

The index analysis suggests that LEH frequency is slightly different between the sites (Fig. 5.14). The lowest value was observed on pig teeth from Wayaogou, and a relatively high value was calculated at Quanhucun, while the pigs from Donglongshan are characterized by the highest LEH index Value. The Lingkou site shows a very large standard deviation, probably because of its small sample size.

As for the interpretation, some assumptions were made as follows: first, low frequencies of LEH in archaeological pig assemblages may reflect access to good quality woodland "pannage" or careful feeding and intensive management by humans, whereas an increase in their frequency may be indicative of decline in the availability of woodland foraging (Ervynck and Dobney 1999); second, the change of LEH index values with time could be related to many factors, such as environmental change, changes in the husbandry regime, or other social-cultural factors.

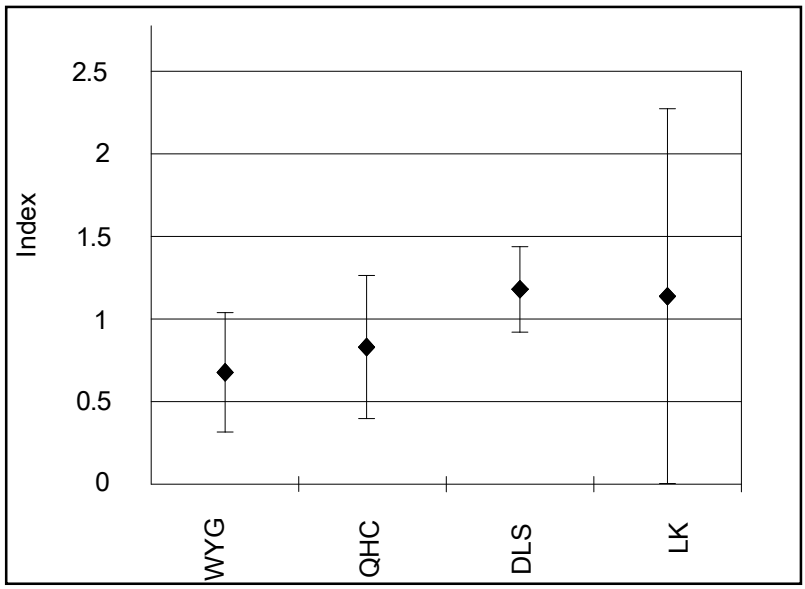


Fig. 5.14 Linear enamel hypoplasia index values for all sites studied (for site codes see Tab. 5.3)

It has been argued that domestic pigs show more LEHs than wild boar (Dobney *et al.* 2007). According to Dobney *et al.* (2007: 71), LEH index value for Chinese recent wild boar is around 0.4. Pig remains from four archaeological sites in the Wei River valley shows LEH index values markedly higher than that of Chinese wild boar. Many phenomena, which are part of the complex of animal husbandry, could account for the increased physiological stress (higher LEH frequencies) in the Neolithic population, such as higher density of animals, inbreeding, change in demographic structure from the wild population and poorly-formulated husbandry strategy.

It can be proposed that the pig populations living at Wayaogou enjoyed better feeding conditions than those at Quanhucun and Donglongshan. Previous research suggests no significant environmental change during the middle Neolithic (see chapter 2). More likely, the variation of the frequencies of LEH in the Neolithic sites of Wayaogou and Quanhucun could result from local different environmental conditions and husbandry strategies. Their range and different frequency of animal taxa suggests that woodland was abundant around the site of Wayaogou (chapter 4). Thus, the woodland habitat could offer suitable foraging opportunities for domestic pig populations. Also, pig remains at the site of Wayaogou comprise less than 40% of the faunal remains, which means pigs were less populated and they may have enjoyed better feeding and living conditions. The relatively higher LEH index for pig at the site of Quanhucun may be the result of intensive rearing in confinement, where food availability was under close human control. Pig remains dominate the faunal assemblage at the site of Quanhucun, with a percentage of over 80, which supports the suggestion that intensive rearing

strategies was practiced for pigs at the site. The cause of the high frequency of LEH at the site of Donglongshan could be much more complicated because climate deterioration from the middle Neolithic to the late Neolithic and early Bronze Age has been suggested by pollen and other evidence (An *et al.* 2004; Feng *et al.* 2006). Hence, climate change could be a factor behind the pattern. Other coinciding factors, such as environmental and habit changes and changes in human husbandry strategies, could also contributed to the LEH pattern in pigs at this site.

The distribution of LEHs on different teeth provides an alternative way of looking at these data. Fig. 5.15 plots the Wayaogou data against the three archaeological data of different periods in this area. The overall outlines are similar although the frequencies vary. The M_3 show a higher frequency of LEH than the M_2 at all sites, which would suggest that for those pigs, stress occurred more often during the second winter than the first.

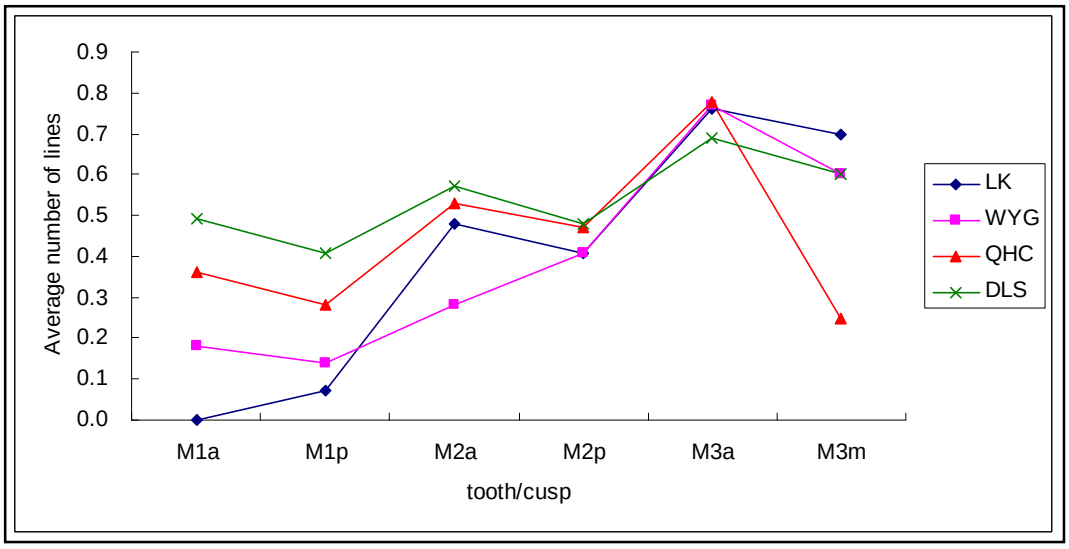


Fig. 5.15 Frequency of tooth cusps with LEH present for four sites studied (for site codes see Tab. 5.3)

5.6.3 Result 2: LEH as a chronological marker

Linear enamel hypoplasia is a deficiency in enamel thickness occurring during the process of tooth crown formation, so it records events during the development stages of animal's life. Considering the tooth growing process, LEH lines formed near the tip of the tooth are actually younger than lines present near the cervix. The M_1 form very early in an animal's life, and consistently show two peaks of LEH lines, interpreted as resulting from the stresses associated with birth and weaning, respectively. The M_2 forms a little later, and a consistent peak of hypoplasias which is quite low on that tooth (relatively late in crown formation) may result from the dietary stresses caused by the animal's first winter (Dobney *et al*. 2004). A broad peak on the M_3 is related to a period of under-nutrition during the second winter. In theory, spring farrowing, autumn farrowing and double farrowing pig populations show different models for the representation of the occurrence of LEH lines given their different life cycles in terms of timing: M_1 consistently shows two peaks of LEH lines, no matter when the pigs were born; for spring farrowing pig populations, the peaks of hypoplasia on M_2 and M_3 located on the lower half of the teeth; for autumn farrowing pig populations, the peak on M_2 and M_3 located on the upper portions of the teeth; for double farrowing populations, two peaks can be observed on the both teeth (Fig. 5.16).

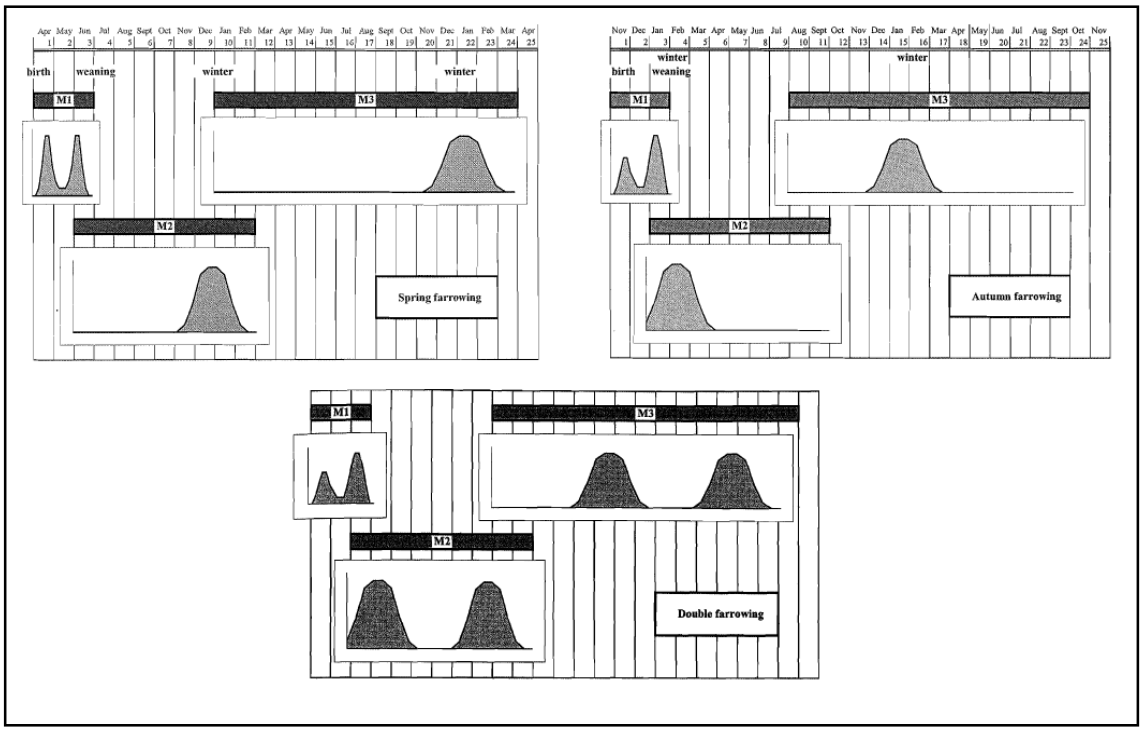


Fig. 5.16 Theoretical representation of the occurrence of LEH on the permanent molars, compared with major events in the life cycle of the primitive domestic pig, for animals from spring farrowing, autumn farrowing and double farrowing (adapted from Ervynck and Dobney 2002)

The frequency distribution of the height of LEH lines on the tooth crown was calculated for all molar cusps (Fig. 5.17). Cusp C of the M_3 has been excluded as the cervical parts are almost always obscured by the ascending ramus of the lower jaw, thus hampering the observations and the measurements of any LEH lines present. Fig. 5.17 shows that the location of the peaks for the same teeth does not differ significantly between the sites and consistent patterns can be observed for all sites. The distribution of LEH for cusp A and cusp B shows two different peaks. On cusp A of the M_1, a clear peak can be observed towards the upper portion of the lingual surface of the crown (around 5.5 mm in height), whereas a relatively broad peak can be observed on the lower portion of the crown (between 2.5-3.5

mm) for cusp B. The LEH peak on cusp A of the M_1 happened during the very early stage of an animal's life and could relate to stress during the birth of the animal. The birth lines seem absent or less prominent on cusp B of the M_1. Instead, the distribution of LEH for cusp B shows a relatively broad peak for the lower portion of the crown, between 2.5 and 3.5 mm. Those lines happened at the relatively later stage of crown formation and could be interpret as weaning lines. The distributions of LEH on both cusps of the M_2 show significant peaks on the lower portion of the crown, located at the same height (around 3 mm). Cusp B of the M_2 shows a broader peak than cusp A. The patterns on M_3 are quite similar to that of the M_2 and a broad concentration of LEH lines can be observed on the lower half of the crowns on both cusps. It is interesting to find that the second cusps of all molars always show a more significant peak than the first cusp.

These observations suggest that there is no great difference between the sites in the location of the peaks on the molar teeth. The locations of the peaks of each cusp on the same teeth are roughly consistent, except for the M_1. This suggests that LEH is not a random event in the pig populations studied and probably the occurrence of LEH at all sites is related to similar events that happened during animals' life. As mentioned above, one serious problem is that the distribution of LEH could be biased by the gradual disappearance of lines a result of occlusal wear. This could lead to an underestimation of the importance of possible concentrations of lines towards the upper portion of the crowns.

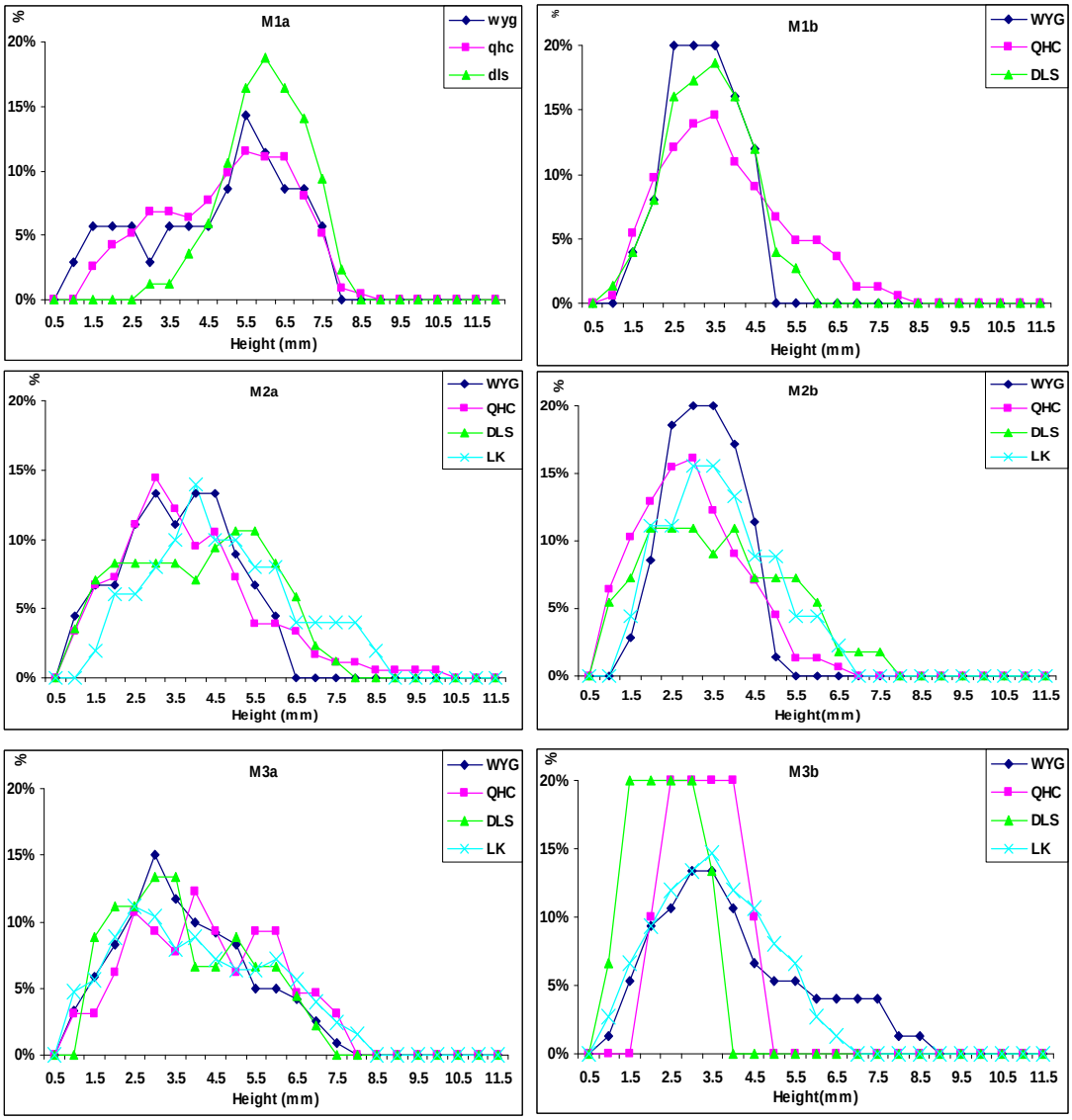


Fig. 5.17 Frequency distribution of LEH height (mm, running means) per LEH type for pig molars (WYG=Wayaogou; QHC=Quanhucun; DLS=Donglongshan; LK=Lingkou)

The distribution of LEH can be interpreted within the chronology tooth development and evaluated against the seasonal life cycle of the domesticated pig, since the enamel is gradually deposited from the tips of the teeth towards the roots during crown formation. The chronology of crown formation has been established by McCance *et al.* (1961) for pigs under two feeding regimes: one, under normal feeding regimes and one, undernourished. Probably, early domestic populations developed more slowly than modern improved breeds and are more comparable to

the under-nutrition population than to the normal ones (Dobney and Ervynck 2000).

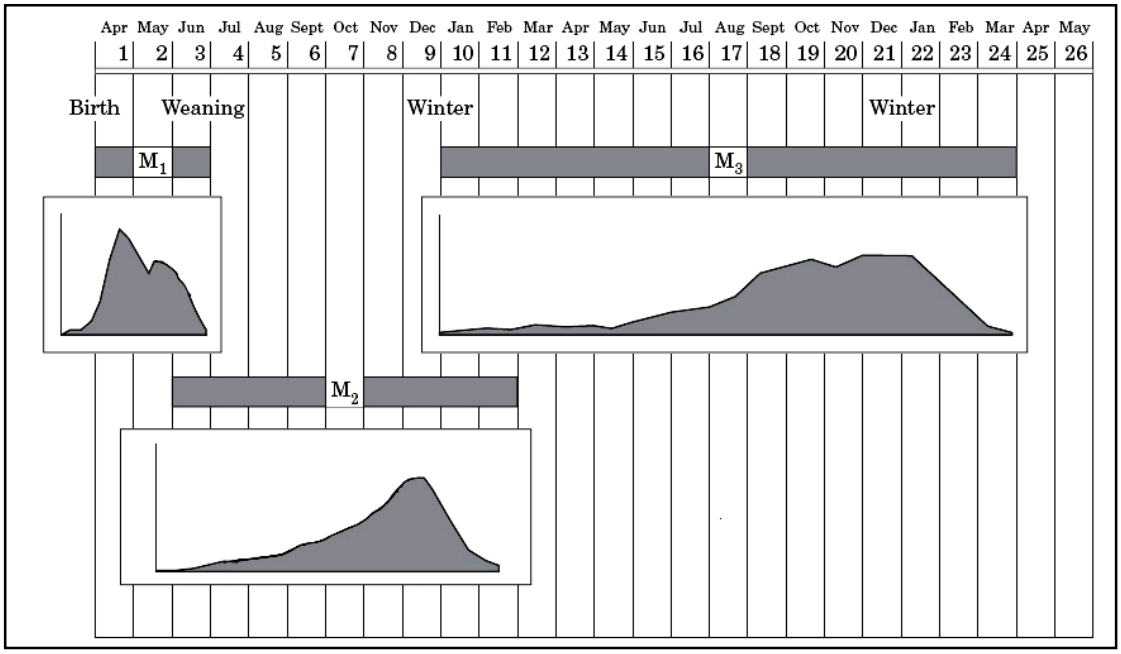


Fig. 5.18 Schematic representation of the occurrence of LEH, compared with major events in the life cycle of the primitive domestic pig from Neolithic sites in the Wei River valley (adapted from Ervynck and Dobney 2002)

In order to have a more comprehensive justification of the occurrence of LEH lines, Fig. 5.18 plots the schematic representation of the distribution of LEH lines compared with major events in the life cycle of the primitive domestic pigs. The crown formation of the M_1 begins in *utero* and is completed by the age of 2 to 3 months (McCance *et al.* 1961). Birth and weaning are the most likely factors to account for the major physiological stresses in relate to LEH peaks on the M_1. Birth, which could cause temporary under-nutrition and a rapid change of environment, is responsible for the occurrence of the first peak on the M_1 (on the upper portion of the crown). It is assumed that weaning in early domestic pigs took place at the same age as for wild boar, i.e. during the third and fourth month

(Dobney and Ervynck 2000). The broad significant peak on the lower portion of cusp A of the M_1 can be explained as reflecting the nutritional stress associated with this event.

If we compare the occurrence of LEH with major events in an animal's life cycle, we may notice that the timing of occurrence of LEH is mostly in winter, so the under-nutrition of the first winter is the factor that causes the presence of LEH on the M_2, and similarly the LEH on the M_3 is related to the second winter. When it comes to the M_2, crown formation begins by the third month and is completed by the tenth to eleventh month. Fig. 5.17 shows that the clear peak of LEH on both cusps of the M_2 is located close to the cervical parts of the crowns. This implies that the stress event responsible for the LEH occurs towards the end of the developmental period of the tooth. It is known that reproduction is a seasonal phenomenon in wild boar (Bull and Payne 1982; Lu 1962; Dobney and Ervynck 2000) and it is reasonable to assume that this was also the case in primitive domestic pig populations. Most wild boars, and probably primitive domestic pigs, were born in spring (March and April). This means that pigs have nearly completed crown formation of the M_2 when they enter their first winter. Winter can be a very difficult time for pig populations in terms of food shortage and bad weather conditions. The peak located at the lower portion of both cusps of the M_2 could be the result of the nutritional stress during the first winter.

Crown development of the M_3 begins during the tenth and eleventh month in the under-nutrition population and crown formation completes before the 21^{st} to 24^{th} month. The distribution of LEH on the M_3 is located on the lower half of the tooth,

with a peak at 3 mm, which could be an occurrence of LEH between 18 to 23 months, which roughly coincides with autumn and winter. It is reasonable to argue that the peaks of LEH distribution on M_3 result from physiological stress during the second winter of life.

5.6.4 Environmental conditions

The index of LEH was calculated by Dobney *et al.* (2007) for pig remains from other sites in China, including Zengpiyan (Guangxi Province, 12,550-7,600 BP), Jiahu (Henan, 7,000-6,200 BP), Yuchisi (Anhui Province, 4,800-4,600 BP), Dongguan (Shanxi Province, 4,400-4,000 BP), Huayuanzhuang (Henan Province, 3,520-3,380 BP) and Fengxi (Shaanxi Province, 3,050-2,750 BP). These sites represent different environmental locations and span from the early Neolithic to the Bronze Age. The general picture suggests that pigs from the Bronze Age (Huayuanzhuang and Fengxi) had a higher LEH index value than those from prehistory, and also the late Neolithic site (Dongguan) shows a significantly higher LEH index than middle Neolithic sites.

Climate change from the middle Neolithic to late Neolithic has been proposed by many researchers. The general pattern is that it was drier and colder in the late Neolithic (An *et al.* 2006; Rosen 2007). Studies suggest there was a significant decline in the number and size of settlements during the late Neolithic in the Wei River valley (Liu 2004). At the same time, there was a significant increase in site numbers in the North Plateau area and central plain of China. The landscape of the Wei River valley may have changed a lot from the middle Neolithic to the late Neolithic, with much woodland and forest disappearing due to the climate

deterioration. All this environmental information suggests that the living conditions for humans and animals may have been changed considerably after the middle Neolithic in the Wei River valley, and the obvious increase of LEH index values of pig probably resulted from the climate change in the late Neolithic.

5.6.5 Double farrowing

Double farrowing of pigs was a common phenomenon for the later period, not only because of economic preference, but also because climate and food supply allow it Whether double farrowing occurs in the primitive domestic population during the prehistoric time has been much debated. As mentioned above, the age structure of pig has been used, trying to trace the phenomenon of double farrowing. LEH analysis can also throw light on the double-farrowing practice of pig husbandry because the distribution of LEH indicates the seasonal life cycle of pig. If second farrowing is applied, this should be visible through LEH patterns on the enamel of the M_2 (Ervynck & Dobney 2002), as LEH can be used as an indicator of the pig's first winter. Piglets that are born in spring (March or April) are about 7 months old when they enter their first winter. Considering the tooth formation process (discussed above), the LEH occurrence caused by the food shortage during this winter should be found on the lower half of the crown. Piglets that are born in autumn were still very young when they entered their first winter, so the depressions resulting from their first winter should locate on the upper half of the crown. The life cycles of the two litters are quite different from each other and they experience winter time at different crown development stages. There should, therefore, be two peaks on the M_2 and the M_3. Fig. 5.17 suggests that there is only one significant peak located on the lower half of M_2 and M_3 at these sites. Thus, probably most pigs at these sites were born in spring, and autumn litters

were rare or absent at these sites. Considering the climate, winter is really harsh in this region, and it is difficult to keep the new born pig alive with the adverse weather condition during the winter time.

In conclusion, there is no clear evidence indicating that double farrowing was practiced at these Neolithic and early Bronze Age sites in the Wei River valley. Thus, probably only one litter of pigs was born each year at the sites.

5.7 Discussion

High frequencies of pig bones at Wayaogou suggest the important status of pig in the subsistence system. Domesticated pigs were identified at Wayaogou based on the following evidence: first, size reduction; obvious size diminution for pigs from early Neolithic sites to middle Neolithic (Wayaogou) can be observed from both the teeth and postcranial measurements; second, most pigs at Wayaogou died before they reached two years old; third, there is relatively larger proportion of pig bones in the faunal assemblages; fourth, animal pen remains were reported at the Jiangzhai site, which represented the same time period as Wayaogou (Banpo Museum *et al.* 1988, Smith 1995: 139); these strongly support close-management.

Metric data on M_3 suggest the size of pigs at Wayaogou falls into the overlap range of domestic and wild populations. Postcranial measurements indicate they are larger than those from later sites. In addition, the frequency of pigs was lower than later periods. Rowley-Conwy *et al.* (2007; 2010) proposed that wide measurement scatters are commonly encountered, but may derive from two separate populations, even though no metrical separation is visible.

Cross-breeding between domesticated pigs and wild boar is a common phenomenon, which has being suggested by some ethnographic studies (Albarella *et al.* 2007). However, recent DNA evidence suggested that domestic pigs in China seem to have been isolated from their wild ancestors completely from the early stages of domestication (Larson *et al.* 2010). The interaction between pigs and humans in Neolithic China seems to show no behavioural intermediacy; rather, there seem to be close-herded domesticates and hunted wild boar. In the case of Wayaogou, a number of M_3 have a length of more than 40 mm and some even close to 45 mm. The Logarithm Size Index technique for studying pig postcranial bones at Wayaogou suggests a relatively low percentage of pigs were larger than the wild boar in southern China (the standard animal in this research). The evidence may support the idea that the hunted wild boar were present at the site, but not dominant. The high frequency of deer and the wide range of wild animals suggest that hunting played an important role in the subsistence. The variety of vegetation and ecology around Wayaogou provided suitable habitat for wild boar. Thus, wild boar can be an occasional prey for human beings.

Climate and temperature may also have influenced the body size of a species. Davis (1981; 1987) pointed out that wild boar tend to be larger in colder climate and smaller in warmer climate. The environmental fluctuations during the Neolithic in northern China have been reviewed by An *et al.* (2004, 2006) and Ren *et al.* (2006), suggesting that the general trend is that it was getting warmer from the early Neolithic to the middle Neolithic. However, whether the climate variations have an obvious influence on the body size change of animals remains a question. Size change of wild species during the Neolithic may provide clues for

this issue, and the size variations of sika deer during the Neolithic will be explored to assess the influence of climate variations in the following chapter.

Cull patterns support a domesticated population at the site, with 90% killed before 24 months old. The majority of pigs were slaughtered as sub-adults and only about 10% reached adulthood. This selective profile is consistent with the classic pattern where 80% or more immature pigs are killed for meat, with a small adult breeding population consisting mostly of sows (Greenfield 1991; Redding 1991).

Reproduction is a seasonal phenomenon in both wild boar (Dardaillon 1988; Rowley-Conwy 2001) and domesticated pigs (Lauwerier 1983, Dobney and Ervynck 2000). The reproduction of domesticated pigs varies due to a number of factors involved in food supply and economic variables. Winter is a challenging season in terms of food supply both for humans and animals and it is responsible for under-nutrition and weight loss (Dobney and Ervynck 2000). Ethnographic studies in Sardinia and Corsica indicate most pigs were killed in winter, before the food shortage of woodland products (Albarella *et al.* 2007).

The birth peak for European pigs is March and September (Lauwerier 1983). However, the LEH analysis at one Neolithic site and four Belgian medieval sites suggest that the majority of pigs were born in spring and double farrowing was uncommon (Dobney and Ervynck 2000). In China, wild boar birthing occurs in April and May (Bull and Payne 1982; Lu 1962). Most domestic pigs give birth in spring and are slaughtered in winter to celebrate the Chinese New Year in remote areas today. Also, if pigs are killed in winter, the meat can be stored for a longer

time or made for ham.

If pigs were born in April, they would have experienced food shortages in their first winter when they reached six or seven months old and their second winter when they were 18 months old. If the farrowing peak for pigs was in September, they would have experienced the first winter after weaning and the second winter when they were 12 months. Tooth ageing suggests that most pigs at Wayaogou were slaughtered between 6 to 24 months old. It is difficult to judge if pigs at Wayaogou were farrowing once or twice every year. However, the cull patterns suggest the majority of pigs were probably slaughtered when the winter comes.

This chapter has discussed the status and management of pigs from Wayogou in detail. How pig husbandry integrated with the rest of the economic system (particularly the animal economy) at the site will be discussed below in chapter 8.

CHAPTER 6
HUNTING PRACTICES FOR SIKA DEER

6.1 Introduction

Sika deer is one of a number of important species in the subsistence system at Wayaogou; about 2947 fragments of sika deer bones were recovered from the site, which comprised 48.36% of all the mammalian remains. Sika deer have been continuously present in China since the Palaeolithic and were widely distributed where forests were abundant in the past. They were extensively hunted to provide food, skins and bone and antler tools in China since the Palaeolithic. Based on the fossil and subfossil record, Guo and Zheng (2000) summarized the geographic history of sika deer in China. During the early Pleistocene, sika deer were only found in north China and Taiwan. In the middle Pleistocene to Holocene, they expanded their distribution over a broad region of central and eastern China. After the ice age, due to both the continuous rising of the Qinghai-Tibet plateau and the development of agriculture, sika deer lost large areas of suitable habitats and their distribution areas shrank once again. Despite this, large quantities of sika deer fragments have been recovered within the structural remains and ash pits at many archaeological sites suggesting that sika deer were frequently hunted by human beings during the Neolithic period.

In this chapter, I will discuss deer hunting strategies based on the analysis of sika deer remains from Wayaogou. The following aspects will be covered: body part representation and taphonomic analysis; metrical analysis; sex and age kill-off patterns. Issues such as taphonomic processes, environmental change, and human

hunting strategies will be addressed.

6.2 Skeletal element representation and the influence of various taphonomic processes

Intertaxonomic differences in skeletal element representation in archaeological faunas may reflect preferences in procurement, processing, transport and consumption of these species by ancient people. The transformation can be broadly categorized as the following: cultural practices, trade, redistribution, butchery, bone manufacture and ritual; disposal strategies; postdepositional taphonomic processes (chemical action in the soil, weathering, and scavenging); archaeological sampling (the choice of the site, parts of the sites or types of context within sites for excavation); recovering procedure (whether or not sieving was carried out, and what kind of sieving) and finally methods of analysis. In this section, various taphonomic factors will be tested to investigate the correlations between taphonomic processes and body part representation.

The body part representation of sika deer was based on the frequency of diagnostic zones expressed as the percentage of expected zones from complete skeletons from the number of animals, as represented by the most common elements. The recording procedures and analysis methods for the sika deer body part representation study were exactly the same as those for pigs: each identifiable specimen is recorded by diagnostic zones defined by the York System database, and the minimum number of elements (MNE) of each body parts is achieved by counting the number of the most frequently present zones. Loose teeth from upper jaws or lower jaws are not counted for duplication reasons. For the maxilla, only

those individuals with at least three cheek teeth are recorded for the body part presentation plots. The percentage representations of different body parts of sika deer are plotted in Fig. 6.1 (original data are in appendix 6.1). The anterior mandible, which is relatively sturdy, were most represented at the site, followed by astragalus and calcaneum, both of which are dense and with no marrow and little grease to provide an incentive for breaking them up. The proximal metatarsal, distal humerus, proximal metacarpal, proximal scapula, distal tibia and proximal radius also survived in relatively large quantities whereas the atlas, axis, phalanges and proximal humerus were less represented at the site.

Structure density of skeletal parts was referred as a factor to mediate various taphonomic processes, such as human ravaging, carnivore gnawing and bone tool production. The time-transgressive or cumulative effect of human ravaging and carnivore attrition is density mediated, which means that bone minerals are lost more rapidly from the low-density elements than from the high density elements. Previous research suggests that the structural density of skeletal parts can exert strong influences on bone survival frequencies (Lyman 1994: 235). The bone density values of sika deer are not available at present, so those of white tailed deer (*Odocoileus spp.)* are used in this study, assuming that *Cervus* of similar body size have similar bone density values. In Fig. 6.2, the % survivorship value of body part zones for sika deer from Wayaogou against bone density of deer is plotted, which suggests that there is a positive correlation between the frequencies of body parts and the structure density, although there is a wide scatter in the data points: the frequency of body parts increases with increased bone mineral density. Thus, it can be proposed that body parts survivorship patterns are influenced by

certain taphonomic processes mediated by bone structure density.

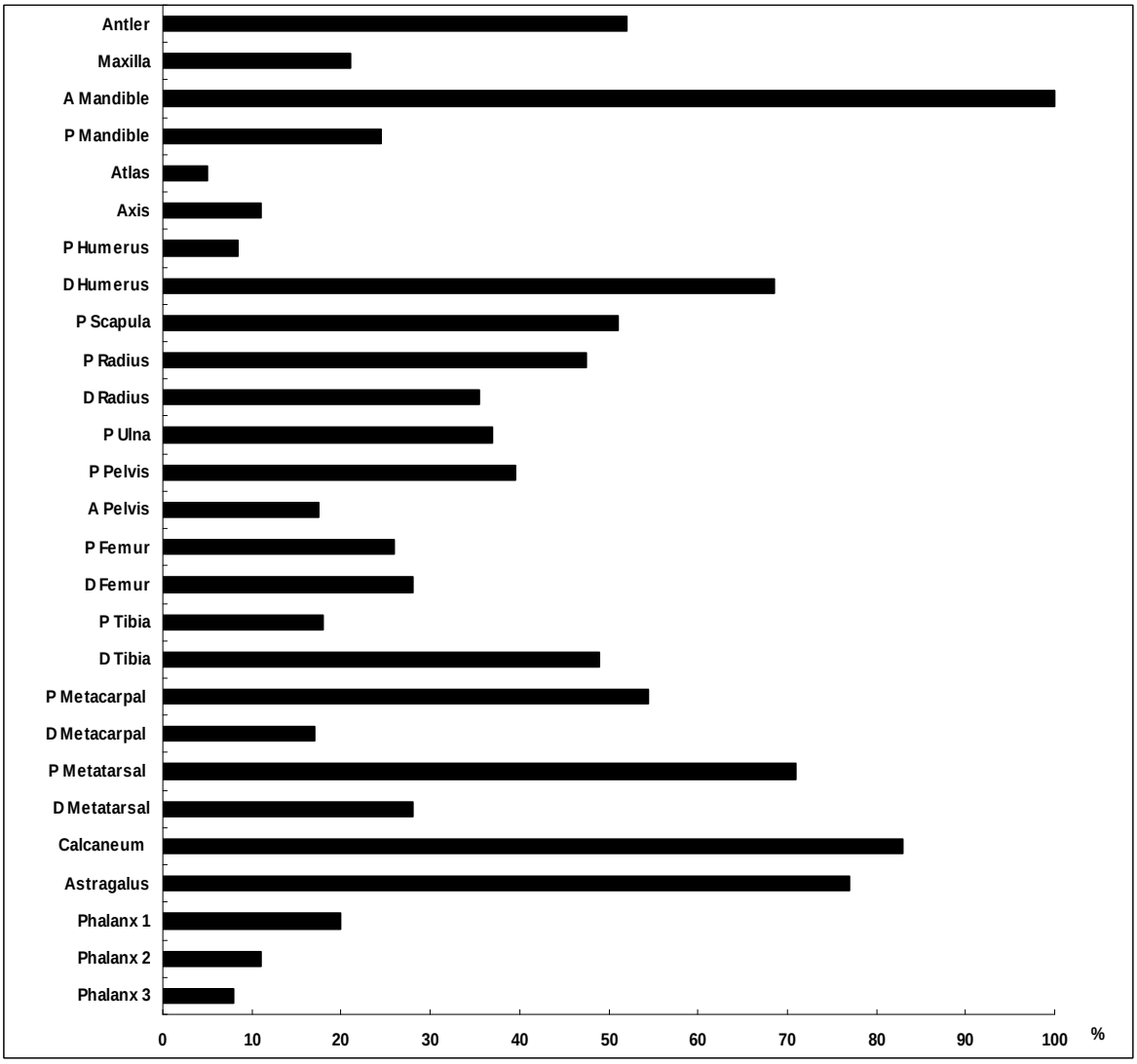


Fig. 6.1 Body part representation for sika deer at Wayaogou, based on diagnostic zones (N=2549)

6.2.1 Recovery bias

Since the excavation of the site was a rescue project, all the bones were recovered by hand collection and no sieving was undertaken. In order to test the biases of different skeleton part representation without sieving, the technique developed by Maltby (1985) was used, by which the frequencies of first and second phalanges

were compared. First and second phalanges occur in equal numbers in the body and are of similar density (Binford and Bertram 1977); they tend to be treated as single unit in butchery. Second phalanges are, however, smaller than first phalanges. In this case, the ratio of second to first phalanges of sika deer is calculated, to give an indication of the degree to which smaller bones failed to be recovered.

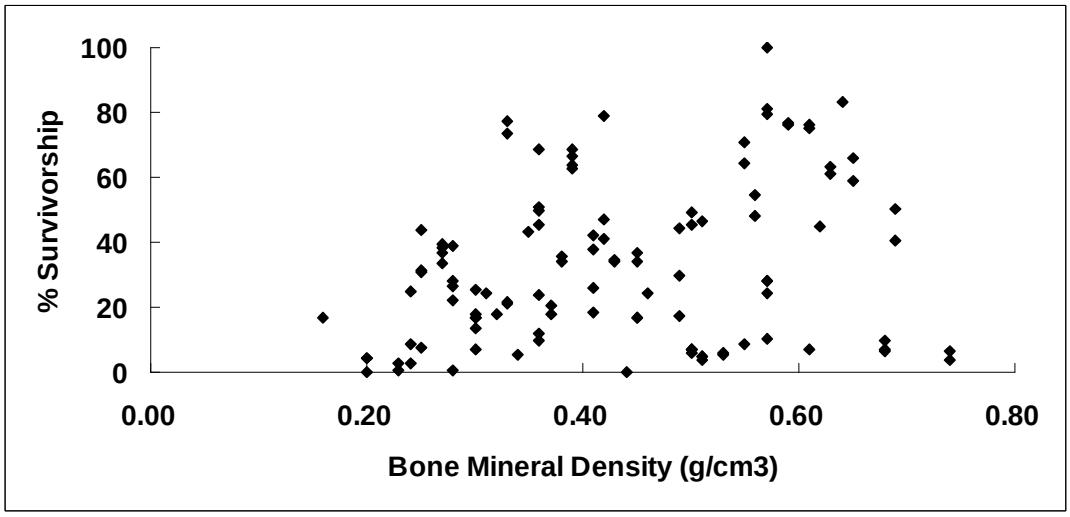


Fig. 6.2 Scatterplot of % survivorship of sika deer skeletal part zones from Wayaogou against bone mineral density values for different skeletal elements of deer (*Odocoileus spp.*) (bone mineral density values after Lyman 1994)

Most sika deer phalanges were recovered in a relatively complete condition at Wayaogou. Two explanations can given made for this: first, the phalanges were less fragmented since they were seldom preferred for bone tool production (see below) and they contain very little marrow; second, some small fragments of phalanges had not been collected during the excavation. The recovery bias at Wayaogou is tested with the technique developed by Maltby (1985). The ratios of second to first phalanges calculated by both number of elements and number of

diagnostic zones are quite close, both around 50%. The results suggest that sika deer first phalanges were much more common than second phalanges and presumably second phalanges only had half the chance to be recovered compared to first phalanges. The test suggests that probably small size bones and fragments were under-represented at Wayaogou. Unfortunately, no sieving was undertaken at the site, which makes it difficult to test to what degree small fragments were misrepresented.

6.2.2 Bone tool production

Another taphonomic process that may affect the frequencies of skeletal parts is the making and using of bone tools. If bones are sufficiently modified during the manufacturing of a tool, they will not be identifiable to skeletal element. More than 200 bone artifacts were recovered from the site and most of them were pointed tools, including awls, chisels, hairpins, needles and arrowheads. Other types, such as sickles and hammer-axes, were also present. From the taphonomic perspective, it is important to identify which element of which species these artifacts were made from. In total, 120 artifacts have been identified to species or taxon level, among which 114 were made from deer elements whereas only six were from pig bones, including 4 canines, 1 femur and 1 scapula. Sika deer bones were much more frequently employed as expedient tools than pig bones (Tab. 6.1), probably because of their appropriate structure, weight and strength. Previous studies suggested that any bones of the skeleton could be expedient tools (Lyman 1994: 344), however, studies from Wayaogou suggest that deer metapodia and antlers were the most frequently used body parts to produce tools (Fig. 6.3). The reasons for this are that they are quite straight and dense and easy to shape. Fig.

6.4 shows examples of worked sika deer bones; splitting and polishing are the most commonly used techniques.

Bone mineral density can be a mediating factor between bone tool production and body part representation, and previous studies suggest that the utilization of bones as raw material for tools may produce a positive statistical relationship between bone density and skeletal part frequencies (Lyman 1994:349). A positive correlation between bone density and the frequencies of skeletal parts of sika deer at Wayaogou can be observed from Fig. 6.2 and an obvious trend is that the frequency of body parts increases the bone mineral density. From this pattern, a proposition can be made that, to some extent, bone tool manufacturing at Wayaogou might have influenced the frequencies of skeletal part representation for sika deer.

Species	NISP	No. of fragments worked	% worked
Sika deer	2947	131	3.9%
Pig	2338	6	0.3%

Tab. 6.1 Frequency of pig and sika deer bones showing evidence of having been worked

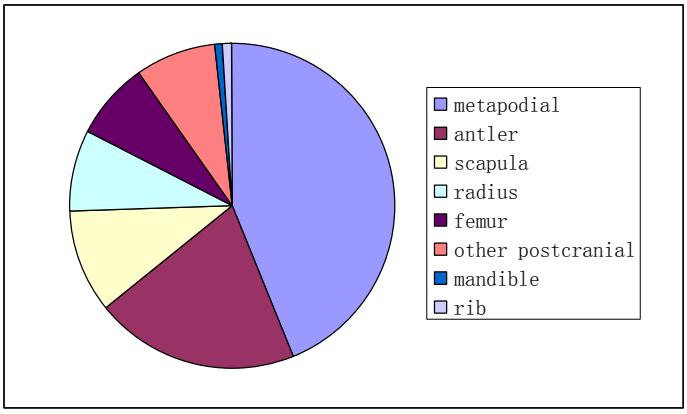


Fig. 6.3 The relative proportions of different body parts from sika deer used for bone tool manufacturing (NISP=114)

Fig. 6.4 Examples of worked sika deer bones (1, worked deer antler; 2, worked deer mandible; 3, sickle, made from sika deer metapodial; 4, polished sika deer metapodial; 5, worked sika deer metapodial; 6, pointed tibia shaft).

6.2.3 Human attrition

Human attrition is another possible factor that could have had a pronounced influence on body part representation. It has been proposed that the extraction of food, such as marrow, grease and fat, may have a significant influence on skeletal part profiles and bones that rank high in nutrient utility will tend to be more fragmented than bones that rank low in nutrient utility (Marshall and Pilgriam 1991). A useful way of measuring the degree of fragmentation of different

skeleton elements is to use NISP: MNE ratios. Some scholars have suggested that the NISP: MNE ratios can be used to assess the extent of, or inter-taxonomic variation in, the exploitation of within-bone nutrients such as marrow and grease (Lyman 1994: 281).

Fig. 6.5 shows the NISP: MNE ratios for sika deer from Wayaogou against the deer marrow utility index. The values of marrow utility index for *Rangifer* are adapted for sika deer in the analysis, because the sika marrow utility index is not available and there appears to be a reasonable amount of interspecies similarity in marrow utility index. The variables are not significantly correlated (r_s=0) and there seems no positive correlation between the NISP: MNE ratio and the bone nutrition index for sika deer. The results suggest that, probably, extraction with-bone nutrients, especially marrow, did not contribute greatly to the skeletal part representation of sika deer at Wayaogou.

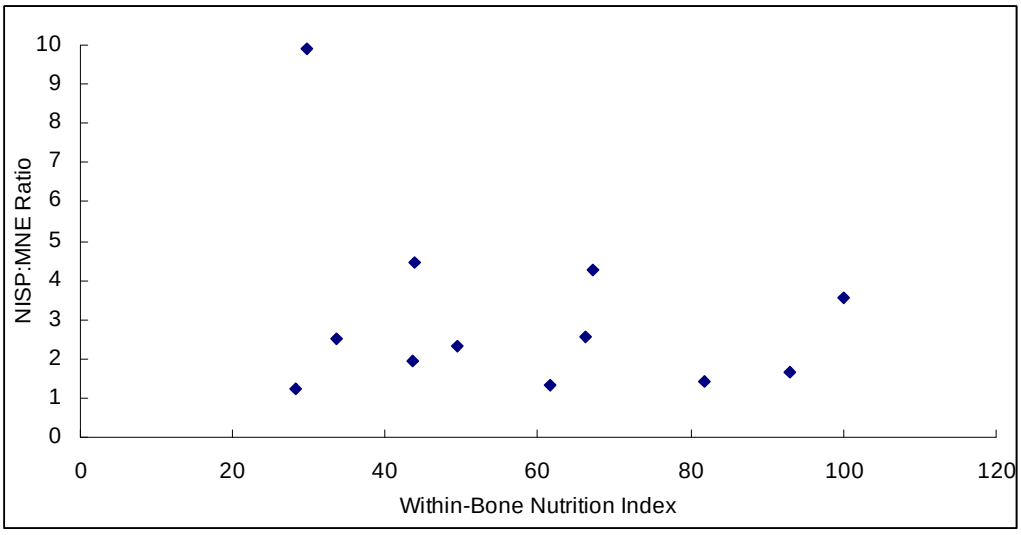


Fig. 6.5 NISP: MNE ratios for sika deer from Wayaogou plotted against within-bone nutrition index for *Rangifer* (index value after Lyman 1994:246)

6.2.4 Dog attrition

Dog attrition is another important taphonomic factor that affects the survival of body parts. Dog remains have been recovered and represent the most common carnivore, and traces of gnawing have been observed on some bones. The influence of carnivore ravaging on the body part representation patterns at Wayaogou is tested in two ways: first, the frequency of dog gnawing present: about 2900 fragments of sika deer bones were present at the site, but only 42 of them show carnivore gnawing marks, which indicates that the percentage of sika deer bones with gnawing marks is quite low (roughly 1.4%).

Thus, the influence of carnivore gnawing could be very limited. The second way to test the effects of dog attrition is to compare the Wayaogou assemblage with other assemblages that have suffered heavy carnivore attrition. Studies of carnivore gnawing effects have been undertaken by Brain (1981), who collected goat bones from modern villages at Kuiseb River in the Namib Desert. Large quantities of dogs in these villages had unrestricted access to the bones after their discard by the villagers. One need to bear in mind two problems when using the Kuiseb River assemblage: first, the work was not systematic and was intended as an observation, which is not analytical; second, one can question the usefulness between taxa. Nevertheless, if Wayagou faunas are plotted, we can see some observable interrelation.

The body part survivorship of the heavily dog-gnawed goat assemblages is plotted in Fig. 6.6 A, and compared with patterns of the sika deer assemblage at Wayaogou (Fig. 6.6 B). Pig elements from the site are also plotted in this graph for comparison (Fig. 6.6 C). Both sika deer and pig bones from Wayaogou are

re-ordered to correspond to the Kuiseb River goat sample and are expressed as percent survivorship. The Kuiseb River goat sample may give a rough impression of the modification to be expected under heavy gnawing, but Fig. 6.6 suggests that there is little similarity between the patterns of Kuiseb River goat and of Wayaogou pig and sika deer. For pigs, the similarity of mandible and distal humerus are high at Wayaogou as in the Kuiseb River assemblage, but the rest of the elements show a quite different pattern. For sika deer, mandibles survived best as in Kuiseb River, but all other elements have different survivorship. Thus, neither pigs nor sika deer resembles the Kuiseb River goats, which supports the argument that dogs have not played a major role in creating the bone survival patterns at Wayaogou. The effects of dog gnawing show different patterns between pig and sika deer, although the relative hardness between elements probably does not vary greatly between pig and sika deer. Thus, the dog gnawing has different effects on pig and sika deer and it is difficult to say which species had suffered more from dog gnawing.

Various taphonomic processes have been investigated to determine which factors have contributed more to the patterns of the skeletal representation at the site. On one hand, it has been suggested that dog gnawing and bone nutrition extraction has played a minor role in producing the patterns of skeletal part representation for sika deer. On the other hand, bone tool manufacturing is an important factor influencing the patterns. From a subsistence point of view, an animal can be considered as both a dietary and raw material source, and considering the hardness and elasticity of bones, sika deer would be an idea species for bone tool manufacturing.

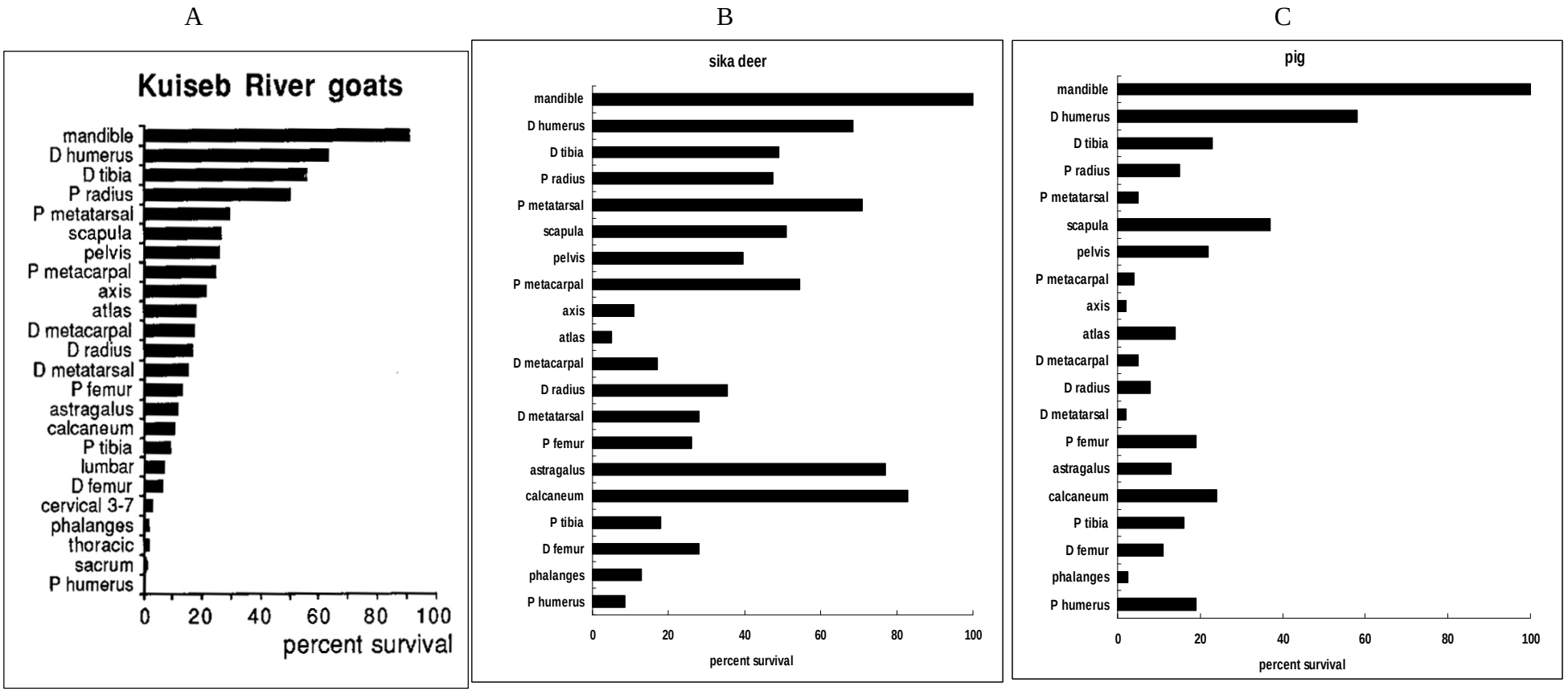


Fig. 6.6 A: Goat bones from the modern settlement at Kuiseb River, arranged in order of percent survival to show the effects of gnawing by dogs (after Brain (1981) Fig.18); B: The frequency of sika deer bone at Wayaogou, expressed as percent survival and re-ordered to conform to the Kuiseb River sample; C: The frequency of sika deer bone at Wayaogou, expressed as percent survival and re-ordered to conform to the Kuiseb River sample

6.3 Morphometrics of sika deer

Size change of fossil species has been commonly used to document natural or human-related selective pressure. Body size in fossil species can be an index of environmental pressure as many animal species change their body size to adapt either to temperature or to forage availability (Klein and Cruz-Uribe 1984; Davis 1987). It has been widely accepted that domestication leads to body size reduction (dwarfing) in most mammal species (Davis 1981). Sika deer is the most common species at Wayaogou as is the case at many sites in China since the Pleistocene. Although the domesticated status of sika deer in Neolithic China has been proposed by some scholars, it has never been widely accepted. Sika deer, which has its origins in East Asia, has been introduced to different parts of the world. Unfortunately, the size variations among these introduced populations and those in East Asia have not been explored, which make comprehensive studies on the relationships between size variation and different environmental factors difficult. In this section, a morphometric analysis of sika deer from Wayaogou and other comparative sites will be presented and the following issues considered: is there size variation between different sites during the middle Neolithic in the Wei River valley and later or earlier period? If size variation is evident, what factors may have contributed: natural factors (eg. habitat change) or human related factors (such as environmental manipulation or hunting pressure)?

Postcranial measurements of sika deer have been obtained from Wayaogou following the standard of von den Driesch (1976) (original measurement data are in appendix 6.2). Most bones of sika deer are highly fragmented since many were used for the manufacture of bone tools at the site, especially the long, dense elements, such as the metacarpals and metatarsals.

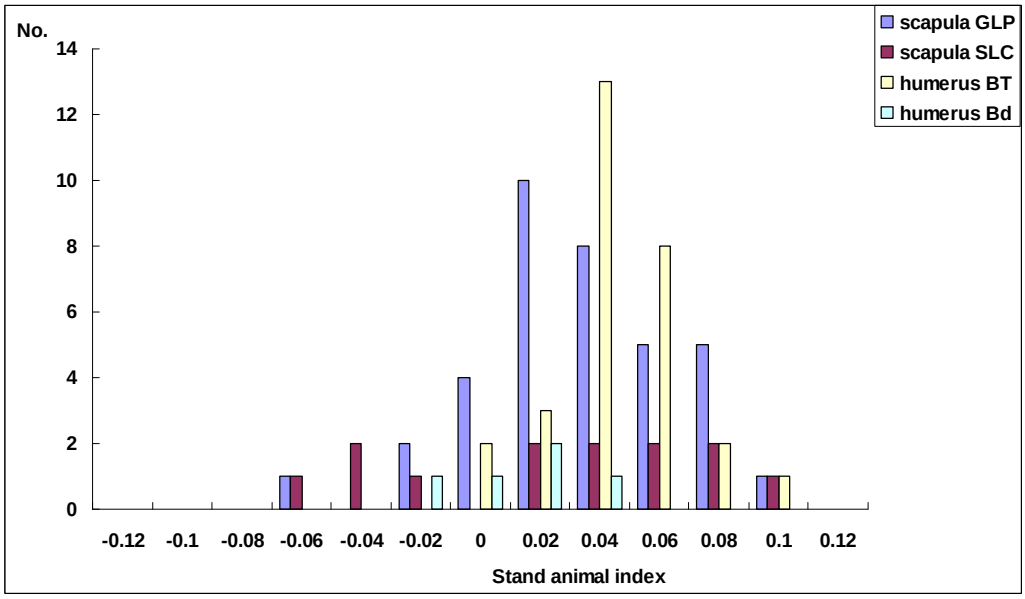


Fig. 6.7 Standard animal values for sika deer postcranial measurements at Wayaogou (n=83). The standard animal is a male individual from Formosa Taiwan, housed in the Natural History Museum, UK; accession number 1865.12.8 (*Cervus nippon raiouanus* 1413.c); only the elements of atlas, scapula, humerus, femur and pelvis are available for measurements; all these body parts have fused epiphyses**.**

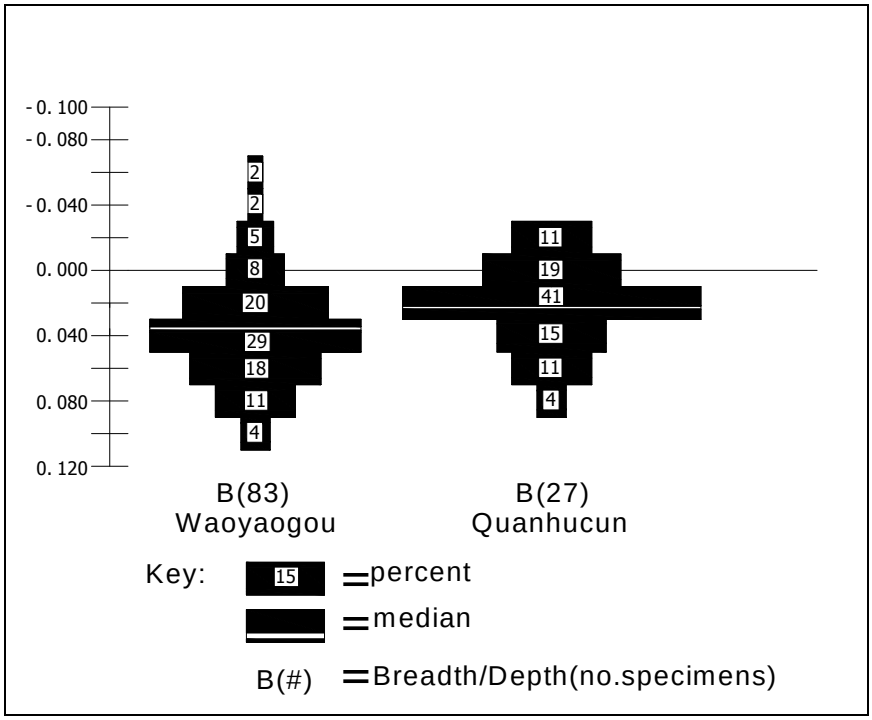


Fig. 6.8 Summary of sika deer log index of body size at Wayaogou and Quanhucun, the median values are also plotted.

The measurements of sika deer from Quanhucun used for comparison are taken from archaeological report of the site (Hu in press). Since the sample size is relatively small, the log size index approach is used in this study (following Meadow 1981, 1999, see Chapter 5 for the details of the methods and its limitations). A male individual from Formosa Taiwan is used as the standard animal, which was collected in the 1800s and housed in the Natural History Museum collection in the UK. Unfortunately, only the atlas, scapula, humerus, femur and pelvis of the standard animal are available for measurement. The measurements of these body parts from the sites are compared via the log size index method to the corresponding parts of the standard. Fig. 6.7 suggests that most postcranial measurements at Wayaogou are equivalent or slightly larger than the standard animal. Similar patterns can be observed when the postcranial measurements at Quanhucun are compared with the standard animal.

Since the standard animal is a modern individual from another area and, as mentioned above, the size of the same species can be influenced by habitat factors, a more convincing way for postcranial measurement analysis is to explore trends through time and compare the trends between different sites and periods. Fig. 6.8 suggests that there is no marked size difference between the Wayaogou and Quanhucun assemblages, which indicates that there is no pronounced size change from the middle phase to the late phase of the Yangshao period. Pollen and plant evidence suggest that the Yangshao period in China experienced the Climate Optimum of the Northern Chinese postglacial and the warm and wet climate lasted for about 2,000 years, until the late Neolithic (the Longshan period) when it began to get colder and dryer. The morphometric analysis of sika deer suggests

that there was no pronounced size change for sika deer, which may indicate different selective pressures. However, some size variation of sika deer between the two sites can be observed: individuals from Quanhucun are slightly smaller than those from Wayaogou. Two possible explanations can be suggested for the size variation observed. Firstly, the habitats of sika deer of the two sites were slightly different, which may impact on the size of the animals. However, whether the habitat differences have influenced the size of the species remains a question. Second, the reduction of the forest and woodland habitats of the species during the Yangshao period may have influenced on the size of the animals. Plant and faunal evidence suggests the expansion of agriculture from the middle phase to the late phase of the Yangshao period, which can result in the clearance of forests and woodland. Previous research on red deer size change in Europe suggests they got smaller since prehistoric times, which resulted from the expansion of agriculture, with red deer losing their habitats in the process (Walvius 1961). If this is the case for the sika deer during the middle Neolithic in China, a similar proposition can be made that the size reduction of sika deer during the middle Neolithic in the Wei River valley was closely related to reduction of forest or woodland habitats as a result of the expansion of agriculture.

6.4 Sex and age profiles

6.4.1 Sex ratio

Two lines of evidence will be used to explore the sex ratio of sika deer at the site: first, the frontlet of the skull can be an indicator for sex as it bears antlers in males; second, body part measurements can provide clues for the sex ratio of wild populations and previous research suggests that certain elements of some deer

species show sexual dimorphism among adults (Legge and Rowley-Conwy 1988).

The preservation of skulls is relatively good and nineteen skulls with frontlets were recovered from the site, of which 15 were from males whereas only 4 were from females. Thus, on the basis of this relatively small dataset, the sex ratio of sika deer can be calculated roughly as 4 males to 1 female. The evidence based on skulls suggests males were preferred in the hunting of sika deer. However, there are two problems with the data: first, the sample size is quite small and the sika deer sample comprises a minimum (MNI) of 137 individuals as determined from the mandibles but only 15 skulls were available for sexing; second, the bias in sex ratios with skull is generally against females because the frontlet used for sexing is more durable in males than in females.

Evidence from the measurements of postcranial bones can also provide clues for the sexing ratio of sika deer since sexual dimorphism in terms of body weight and height is considerable in modern sika deer populations. The problem is that large comparative samples of sexed sika deer skeleton from the same population are not available, thus, to what degree sika deer shows sexual dimorphism and what elements show sexual dimorphism is an open question.

Postcranial measurements can also provide clues for the sex ratio of sika deer at the site. Most postcranial elements of sika deer are not present in sufficient numbers for any patterning to be observed. The astragalus, which is relatively dense and less influenced by various taphonomic factors, was present in relatively large numbers which are sufficient for analysis. Fig. 6.9 plots the greatest length

of the lateral side of the astragalus against the distal breadth. It shows that the size range is quite wide indicating that both sexes were present. Assuming that the males concentrate in the upper part and females in the lower part of the distribution, there should be some overlap between them. Thus, it is difficult to determine the sex preference of sika deer with these measurement data.

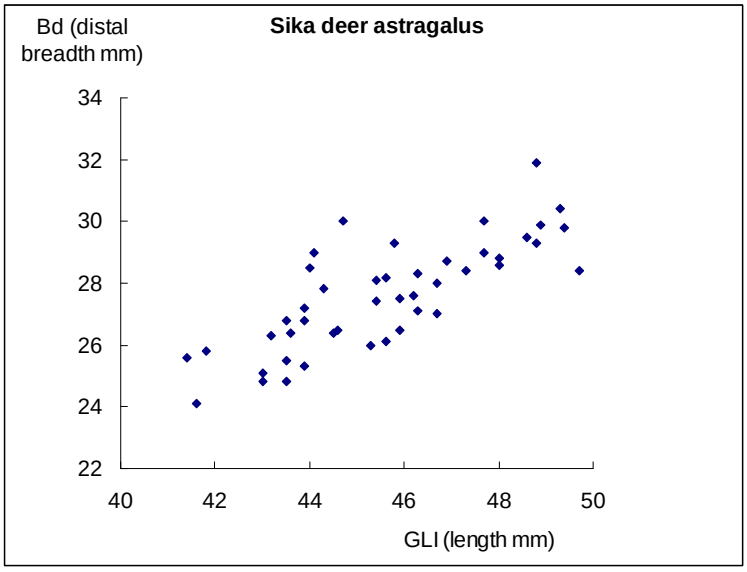


Fig. 6.9 Distribution of sika deer astragalus measurements from Wayaogou

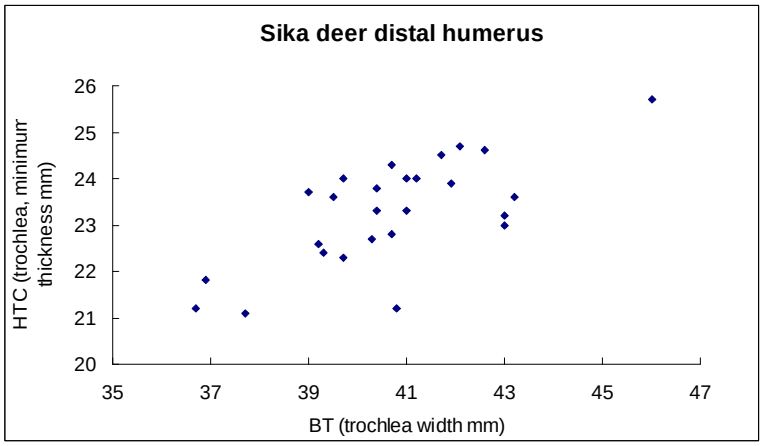


Fig. 6.10 Distribution of sika deer humerus measurements from Wayaogou

Measurements of distal humeri are plotted in Fig. 6.10. It suggests that sexual

dimorphism for the distal humerus is not so obvious and most of the data were concentrated, with a few outliers. The explanation for the pattern is that the sample is not big enough to observe sexual dimorphism, or these two measurements of the humerus are not sexually dimorphic.

Evidence from skulls suggested that more males were hunted at the site than the females. However, in the absence of measurements from modern comparative animals of known age and sex, a tentative conclusion can be made that there was slightly sexual bias in favour of males for the sika deer hunting strategies at the site. As mentioned above, antlers, which are only produced by males, are an ideal raw material for tool manufacturing at the site. Thus, it is possible that males were preferred by human beings during hunting activities.

6.4.2 Fusion ageing

Sika deer fusion sequences and age were established based on the observation of modern samples from Killarney National Park (KNP) County Kerry, Ireland (Carden 2006). According to Carden (2006), the proximal scapula, distal humerus and proximal radius fuse first, before two years of age. The second epiphyseal suture fusion group includes the proximal ulna, proximal ulna, proximal humerus, distal femur and proximal femur, which fuse by five years old. All sutures of bones from the fore limbs and hind limbs are fusing or fused before eight years of age. Post-cranial body parts from Wayaogou were put into four groups according to the sequence of epiphyseal fusion and the rough ages were estimated based on bone fusion patterns (Tab. 6.2).

The survivorship curve of sika deer based on epiphyseal fusion are plotted in Fig. 6.11, suggesting that the 99% of sika deer from Wayaogou survived to more than 24 months old, which means very few of them were killed before two years old. More than 60% of sika deer survived beyond stage IV, suggesting that most of them were slaughtered when they were more than six years old, i.e. as adults.

As mentioned in the previous chapter (4), there are serious flaws with the interpretations of fusion data, so, fusion ageing can not be the only method used for establishing kill-off pattern of species from archaeological sites.

Stages	Fusion age (months)	Epiphyses	Number fused	Number unfused	Number fusing	% unfused	% fused (survivorship)
		Scapula	100	0	1	0.00	
		distal humerus	122	3	13	2.17	
		proximal radius	99	0	1	0.00	
I	0-24	**Total**	**321**	**3**	**15**	**0.88**	**99.12**
		proximal ulna	13	13	1	48.15	
II	24-48	**Total**	**13**	**13**	**1**	**48.15**	**51.85**
		proximal humerus	12	6	3	28.57	
		proximal femur	37	25	2	39.06	
		distal femur	31	17	5	32.08	
III	48-60	**Total**	**80**	**48**	**10**	**34.78**	**65.22**
		distal radius	45	29	9	34.94	
		proximal tibia	18	19	4	46.34	
		distal MT	27	15	2	34.09	
IV	60-72	distal MC	17	9	1	33.33	
		Total	**107**	**72**	**16**	**36.92**	**63.08**

Tab. 6.2 Survivorship based on epiphyseal fusion for sika deer from Wayaogou; epiphyseal fusion stages given by Carden (2006)

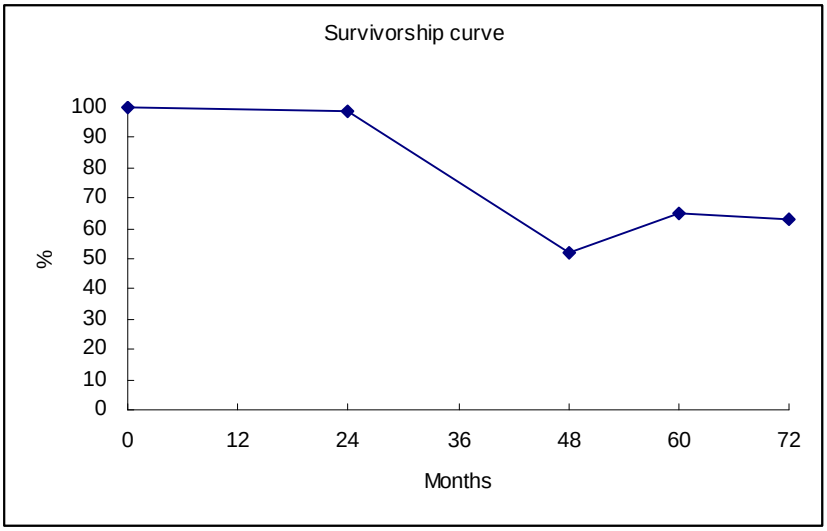


Fig. 6.11 Survivorship curves of sika deer based on epiphyseal fusion from Wayaogou

6.4.3 Dental ageing

Methods

Combined tooth eruption and wear schemes are the most reliable way to assess the ages of animals from archaeological sites. So far, the schemes described by Payne (1973) for sheep/goat and these by Grant (1982) for cattle and pig are the most commonly used ones, but they are inappropriate for deer taxa. The score schemes devised by Brown and Chapman (1990, 1991) for red deer and fallow deer have been used to assess the age of deer from archaeological sites as they are quick and effective. This method can also be adapted to other ruminant species with the appropriate baselines. Another method that has been used to estimate the age of deer is by observation and measurement of the annual layer of tooth cement (Koike and Ohtaishi 1985), but it requires special equipment and techniques and is time consuming and destructive to the samples; also the reliability of the method needs to be tested. Additionally, measurements of crown height have been

used to determine the age structure of deer from archaeological sites, and have been applied to some faunal assemblages (Koike and Ohtaishi 1985, Morrison and Whitridge 1997). In this study, the schemes designed by Brown and Chapman are adapted for sika deer ageing. Tooth eruption and wear sequences are determined by observing and recording modern samples from Japan, the results of which have been published by Japanese scholars (Ohtaishi 1980, Koike and Ohtaishi 1985).

The wear characteristics of sika deer (*Cervus nippon*) are very similar to that of fallow deer and red deer, given their similar body size and habitats. The methods devised by Brown and Chapman for fallow deer and red deer were easily applicable to sika deer at Wayaogou, providing a good way to assess the ages of adults at the site. Meanwhile, the tooth eruption stages were also recorded which can be used to age the relatively young individuals.

According to Ohtaishi (1980) and Koike and Ohtaishi (1985), the teeth of sika deer erupt and wear in the following sequence (Tab. 6.3): the lower M_1 appears about 4 months after birth, in the autumn of the first year, and grows to occlusal state in the first year; the lower M_2 appears at about 12 months of age, in the summer of the second year, and its wear begins within the second winter; eruption of the lower M_3 begins about 20 months after birth, in the early spring of the third year. Full permanent teeth are in place at about 24 months after birth, in the summer of the third year. Following this sequence, the age stages of young individuals of sika deer at Wayaogou can be defined.

Winter	Age (months)	Tooth eruption			
1st	0	$i_1\ i_2\ i_3$	c	$dp_2\ dp_3\ dp_4$	
	6	$i_1\ i_2\ i_3$	c	$dp_2\ dp_3\ dp_4$	M_1
	12	$i_1\ i_2\ i_3$	c	$dp_2\ dp_3\ dp_4$	$M_1\ M_2$
2nd	18	$I_1\ I_2\ I_3$	c	$dp_2\ dp_3\ dp_4$	$M_1\ M_2$
	24	$I_1\ I_2\ I_3$	C	$dp_2\ dp_3\ dp_4$	$M_1\ M_2 M_3$
3rd	30	$I_1\ I_2\ I_3$	C	$P_2\ P_3\ P_4$	$M_1\ M_2 M_3$

Tab. 6.3 Tooth eruption and replacement in sika deer, after Ohtaishi (1980) and Koike and Ohtaishi (1985)

The tooth wear sequence of red deer and fallow deer has been described by Brown and Chapman (1990, 1991) in detail: the mesial slopes of the paired mesial cusps in the molar teeth are the first to be worn, followed by wear on the distal cusp slopes. As opposing teeth come into contact, the covering enamel of the cusps is worn away revealing the underlying dentine. With time, more and more of the cusp is worn away and, to prevent the central soft tissue pulp chamber of the cusp being exposed to saliva, increments of secondary dentine are deposited by odontoblasts on the internal wall of the dentine. Because this secondary dentine is deposited incrementally, teeth have characteristic wear patterns, enabling an assessment of age to be made. As wear proceeds, the mesial and distal marginal ridge dentine and the dentine between the paired mesial and distal cusps becomes exposed.

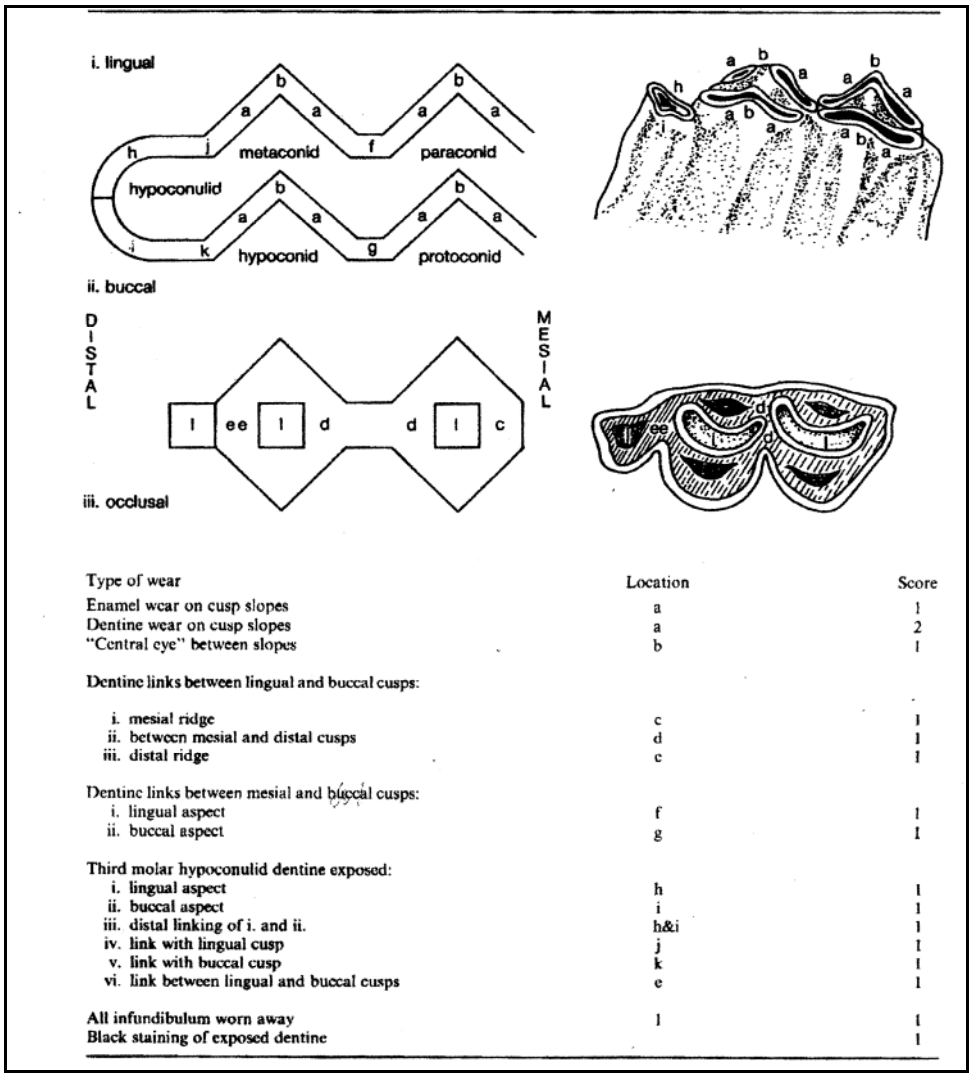
Based on a clear understanding of the sequential nature of the tooth wear process, a systematic score and recording system was devised (Brown and Chapman 1990, 1991) (Fig. 6.12): to score the molar wear patterns, each slope of a tooth cusp that had only worn enamel was given a score of one (a, Fig. 6.12). When the

underlying dentine was exposed a score of 2 was given. An additional score of one was given when:

1. The dentine between mesial and distal slopes shows a central white eye (b), indicating the central zone of secondary dentine in the pulp.
2. The dentine was exposed to link the dentine of the lingual and buccal cusps (c, d, and e). This could be between mesial and distal cusps. There are five locations where this could take place: the mesial and distal marginal ridges and the dentine between paired mesial and distal cusps.
3. The mesial and distal cusps were worn so there was a continuous joining line of exposed dentine between the two cusps on either the lingual and buccal aspect of the tooth (f, g).
4. The exposed dentine linking the lingual and buccal cusps, and the exposed dentine linking the mesial and distal cusps, were stained dark brown.

The unique shape of the most distal cusp of the third molar, the hypoconulid, presents special problems. On point each was given for wear on the lingual and buccal sides (h, i), and an additional point when the two wear sites were joined together. A further point was given when the lingual or buccal dentine was linked with that of the metaconid or hypoconid.

The preservation conditions at Wayaogou are adequate and the sika deer mandibles usually had all the molar teeth *in situ*. Following this system, 67 mandibles with two or three molars present from Wayaogou were scored and the cull structure of sika deer was obtained (appendix 6.3).



Type of wear	Location	Score
Enamel wear on cusp slopes	a	1
Dentine wear on cusp slopes	a	2
"Central eye" between slopes	b	1
Dentine links between lingual and buccal cusps:		
i. mesial ridge	c	1
ii. between mesial and distal cusps	d	1
iii. distal ridge	e	1
Dentine links between mesial and buccal cusps:		
i. lingual aspect	f	1
ii. buccal aspect	g	1
Third molar hypoconulid dentine exposed:		
i. lingual aspect	h	1
ii. buccal aspect	i	1
iii. distal linking of i. and ii.	h&i	1
iv. link with lingual cusp	j	1
v. link with buccal cusp	k	1
vi. link between lingual and buccal cusps	e	1
All infundibulum worn away	1	1
Black staining of exposed dentine		1

Fig. 6.12 Tooth wear schemes for fallow/red deer showing the locations for scoring the third mandibular molar; the first and second molars are identical but without the distal hypoconulid (from Brown and Chapman 1991: 524).

Results

Based on the tooth eruption and wear score values (P_4, M_1, M_2 and M_3), ten mandible wear stages were defined for sika deer at Wayaogou. Since the wear patterns of known age of sika deer have not been studied and are not available to compare with archaeological remains, two ways have been used here to determine the exact age of sika deer from the site: first, tooth eruption information, especially the eruption age of P_4, M_1, M_2 and M_3 (Tab.6.3); second, tooth wear

scores and patterns for red deer. Similar wear rates in the older population for sika deer and red deer have been observed by researchers, although in younger populations, sika deer molars wear more quickly than that of red deer (Uchiyama 1999). Assuming sika deer reach the same age as red deer when they have a similar wear stage, rough ages can be calculated for the sika deer at the site, ranging from 4 months old to more than 8 years old (Tab. 6.4). The resulting data for sika deer tooth eruption and wear stages at Wayaogou is shown in Fig. 6.13, suggesting that most sika deer were killed at a later stage in the dental development sequence, when all cusps of M_3 were in wear.

MWS	**Tooth wear stages**	**Notes**	**Age (months)**	**No.**
1	dp_4 slightly wear; M_1 in crypt		4	1
2	dp_4 slightly wear; $M_1 \leq 8$	M_1 enamel worn only	6	2
3	dp_4 moderate wear; $M_1 \leq 26$; M_2 erupting	M_1 enamel and dentine all worn; M_2 erupting	12	9
4	dp_4 heavily worn; $M_1 \leq 30$; $M_2 \leq 20$; M_3 erupting		24	8
5	P_4 erupting; $M_1 \leq 30$; $M_2 \leq 26$; $M_3 \leq 8$	M_3 enamel worn only	36 or older	4
6	$M_3 \leq 24$	M_3 enamel and dentine all worn	48 or older	5
7	$P_4 \leq 5$; $M_2 \leq 30$; $M_3 \leq 30$	P_4 in wear	50-55 or older	11
8	$P_4 \leq 10$; $M_1 \leq 35$; $M_2 \leq 35$; $M_3 \leq 36$		63-78	17
9	$M_3 \leq 40$	Old	92	7
10	$M_3 \geq 40$	very old		3

Tab. 6.4 Wear stages of mandibular teeth in sika deer from Wayaogou

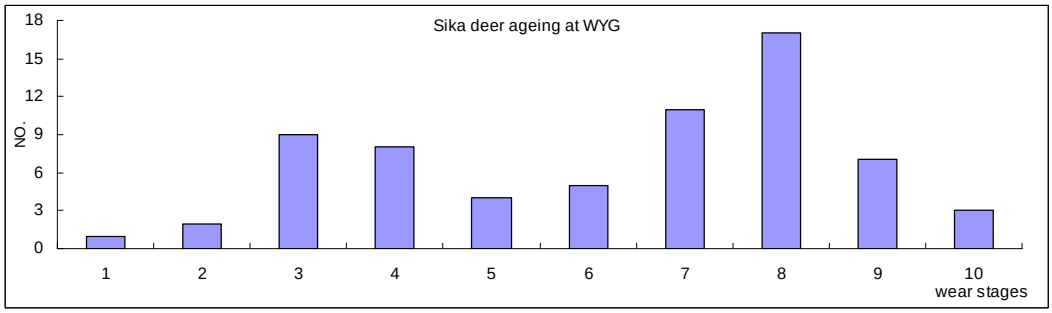


Fig. 6.13 Cull patterns of sika deer at Wayaogou based on tooth eruption and wear stages (N=67)

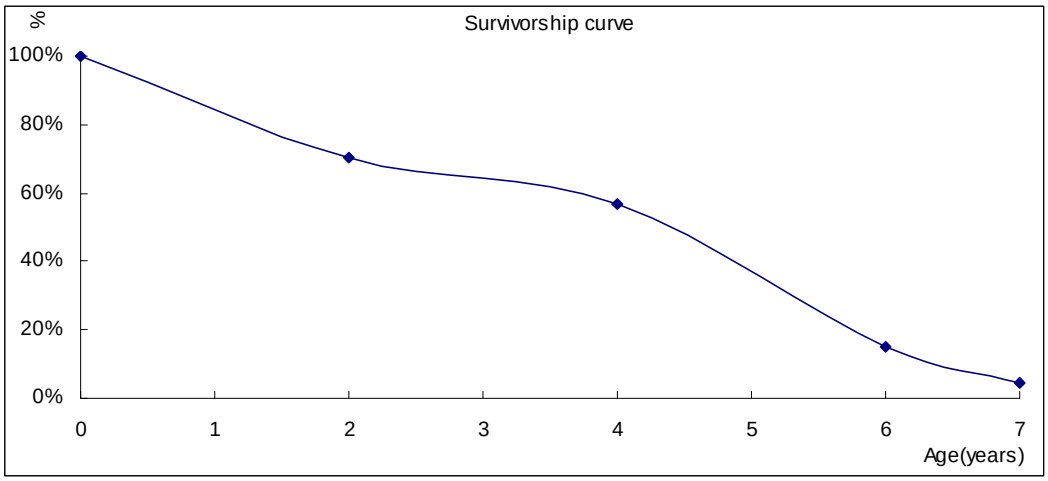


Fig. 6.14 Survivorship curve for sika deer at Wayaogou (N=67)

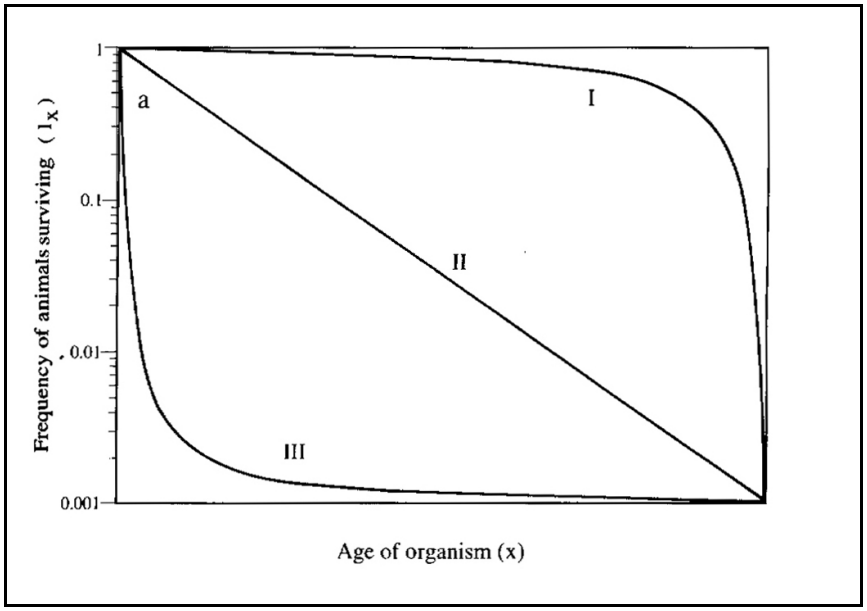


Fig. 6.15 Three theoretical curves of animal survivorship (after Deevey 1947)

Fig. 6.14 plots the frequency of individuals surviving at the site against the age of the animals. Theoretically, three types of survivorship curves of different life history patterns for animals have been proposed (Deevey 1947, Fig. 6.15). Type 1 forms convex curve indicating the mortality of the population is very low until old age, termed as K strategy. Type II is plotted as a straight line indicating that the death rate is consistent at each age. Type III takes the form of a concave curve indicating a high probability of death among foetal and young individuals but once individuals have survived this vulnerable period they have a good chance of reaching maturity (R-strategy). The life history pattern of sika deer at Wayaogou falls between the theoretical type I and II. With this pattern, it can be proposed that there is age related death rates in the assemblage. However, relatively high mortality can be observed in two age groups: the first death peak came when the animals were 1 to 2 years old; the second is between 4 to 6 years old. However, the second death peak is much more obvious than the first, indicating that large numbers of animals were killed between 4 to 6 years old.

There is a significant difference between the kill-off patterns observed from the tooth eruption and wear data and those from epiphyseal fusion. Considering the serious problems in the interpretation of fusion data (see chapter 5), here the interpretation of sika deer ageing will be based on the patterns observed from the tooth eruption and wear stages.

The age composition of living sika deer populations has been observed in Japan (Ohtaishi 1975, 1976, 1978, cited from Koike and Ohtaishi 1985). The physiological longevity of sika deer under well-fed, protected conditions (Nara

Park populations) is 26 years for female deer and 21 years for males. The maximum longevity of sika from Kinkazan Island (deer were protected and no hunting was undertaken) was slightly shorter than that of park deer. The maximum life expectancy of the hunted wild deer was only half of the maximum and animals over 5 years old were few and those of more than 8 years were very rare. The age structure of sika deer at Wayaogou is similar to the hunted wild deer population in Japan and most individuals died before eight years old. No evidence suggests that sika deer were fed by human beings; the animals were living in wild conditions and hunted frequently.

The annual probability of survival (mortality) varied with age in sika deer. Fawns experienced the highest rate of mortality and were particularly sensitive to environmental conditions; fawn or calf mortality in ungulate species is known to occur mainly within the first few weeks and during the first winter (Guiness *et al.* 1978). No evidence from the age profiles based on tooth eruption and wear suggests that fawns experienced higher mortality or winter death. Thus, it can be proposed that the age structure of sika deer at Wayaogou is more related to human activities, than to natural or environmental factors.

The life histories of sika deer can be represented in terms of four life-stages: new born (calf), yearling, juvenile (2-3 years old), and adult (more than 3 years old) (Miura and Tokida 2009). Data correlating to body weight and age of sika deer suggests that body growth curves may generally be divided into three phases: rapidly increasing weight until three years, stabilizing until about 10 years and gradually declining thereafter. Kill-off patterns suggest that most sika deer at

Wayaogou survived until they reached 4 years old, which indicates most deer were hunted when they were adults and had reached maximum body weight. Very few sika deer died between two years old and four years old. Sika deer reach their sexual maturity at 18 months and two to four years old is the best mating age for the animal, so the low mortality at these ages perhaps suggests that “conservation hunting” was practiced, probably for the reproduction of the animals. Hence, the proposition can made that specific hunting strategies were practiced for sika deer by human beings, who would have had familiarity with the species behaviour. Also, the adult dominated assemblage suggests that the hunting pressure was relatively low, making it possible to keep deer alive for a longer time.

Another death peak for sika deer came when the animals were between one and two years old. Considering the behavior of the animals, sika deer of this age are just leaving their mothers and they would inexperienced and more vulnerable, so they are more easily hunted or trapped. Thus, the high probability of mortality in this age group probably reflects the hunting of subadults after leaving their mothers.

6.5 Seasonality of sika deer hunting

There is a strong suggestion that Wayaogou was occupied all the year around and people lived in a sedentary lifestyle, since millet agriculture and pig husbandry was practiced intensively at the site (see discussion in Chapter 8). However, whether sika deer were hunted in specific seasons or all year round remains an interesting question, given their seasonal life cycle. Typically, the breeding season of sika deer occurs from the end of September to November and females give

birth to one calf after an eight months gestation period, usually in late May to July. The young become independent and leave their mother after 7-10 months (Nowak 1991; Sheng 1992; Animal Diversity Web, University of Michigan Museum of Zoology 2011). The males shed their antlers in April or May and grow new ones during the summer, getting ready for the autumn rutting season.

Various lines of evidence can be used to indicate the seasonality. Studies of tooth eruption patterns and analysis of cementum layers in teeth are the most commonly used methods. Cement analysis has not been the focus of this study and tooth eruption will not be used since there are no detailed comparative samples. Since sika deer shed their antlers seasonally, antlers and skulls, either holding antlers or with antlers shed, will be used here to infer the seasons of deer death.

Large quantities of sika deer antlers were recovered from the site, although most of them are quite fragmented. The antlers were sorted into two groups: those that were naturally shed and those removed from the skulls by humans. Naturally shed antlers can not be used as a seasonality indicator as they could be collected and stored from one season to another. This is no doubt the case at Wayaogou as sika deer antlers were one of the most frequently used raw materials for tool manufacturing. Individuals with antlers removed from the skull suggest a rather wide range of killing time, from the autumn to the spring of the next year (September to April) when the males bear antlers. Examination of cervid crania with frontlets present can also provide information on whether antlers have been removed or shed naturally. Skulls with chop marks on the pedicle suggest that the animals died with antlers present, between September to April. Skulls from which

the antlers have shed or with antlers growing suggest that the animals were killed from May to August, since this is the season that the old antlers had just been cast from the head and new antlers were in development.

	Season	**Descriptions**	**No.**	**Total**	No. per month
Group 1	**Sep.-Apr.**	Skulls with antlers	9	30	3.5
		Antlers chopped or broken from the heads	21		
Group 2	**May-Aug.**	Skulls from which the antlers have shed or with new coming antlers	7	7	1.75
Group 3	**All year around**	Naturally shed antlers	34	34	

Tab. 6.5 The seasonality of sika deer based on antlers and skulls from Wayaogou

The antlers and skulls were put into different groups, according to different seasonality information yielding (Tab. 6.5). In total, 55 antlers and 16 skulls provided information, which represents a total of 71 male deer at the sites. Thirty of them were killed during the season when the antlers were present, from September to April, and only 7 died when the antlers were absent, from May to August. If the number of sika deer from each group is divided by months, 30 individuals died within 8 months (3.75 individuals per month) and 7 died within 4 months (1.75 individuals per month). The results suggest sika deer were killed all year around, although more individuals were killed during the winter time.

According to a field census of a living deer population in Nikko Park (Maruyama 1981, cited from Ito and Tekatsuki 2009), deer congregate between December to April, and central zones of these congregations are of high density, consisting of

female deer accompanied by fawns, which are surrounded by male deer at the fringes. Deer herds are more vulnerable during this season and probably more deer were hunted. The sex ratio suggests that more male sika were killed than females at the site and males had more chance to be targeted as they are always at the fringe of the herds during the aggregation season. Male-preference hunting strategies have been proposed above and obviously an aggregation season is an ideal time for humans to hunt.

6.6 Discussion

High frequencies of sika deer remains at the site suggest that deer hunting played an important role in the subsistence system, although pig domestication and husbandry were also practiced at the site. Various aspects of deer hunting strategies have been investigated here, including taphonomic process analysis, morphometric studies and age and sex profile analysis.

It seems that bone tool production had significant influences on the frequencies of skeletal part representation for sika deer, whereas other agents, such as carnivore gnawing and human marrow extraction, had less pronounced effects on the survival of body parts. However, the taphonomic process was complicated and it is difficult to determine which factors contribute most to the skeletal-part survivorship patterns.

Morphometric studies suggest that the size change of sika deer during the middle Neolithic was not so pronounced compared with the size change of pigs. Thus, if the sika deer, which have a relatively consistent body size over time, are used as a

controlling animal to mediate the influence of environmental change, the obvious size change of pigs throughout the Neolithic were probably more related to human domestication and husbandry activities rather than to environmental variation. However, size variation of sika deer can be observed at different sites of different periods and it seems that sika deer were getting smaller in the late phase compared to the middle phase of the Yangshao period. The size variations of sika deer may result from the habitat difference between the sites. Of course, it is possible that the sika deer experienced certain hunting pressure during the late Yangshao Period, and possibly, the intensification of agriculture and expansion of farm land resulted in clearance of woodland and forest, which would affect the habitats of sika deer and size change of the species.

The age profile of sika deer suggests that most deer were killed when they were adults and had reached their maximum body weight. The pattern indicates that hunting pressure of sika deer was relatively low at Wayaogou. Also, the best mating age for sika deer is between two years old to four years old and relatively small proportions of sika were killed at this stage, indicating conservation hunting strategies were practiced and the reproduction of the species was considered by humans. Evidence from skulls and antlers suggest that more sika deer were hunted during the seasons when the males bear antlers, which mainly is between September to April. This is the season when the species congregates. The raw materials for bone tool manufacturing are mainly from the sika deer elements whereas the body parts of pig were seldom used. Hence unlike pigs, sika deer were not only exploited for meat but also for the antlers and bones which were ideal raw material for bone tool manufacturing.

This chapter attempted to understand human hunting activities of sika deer in the Neolithic China. Obviously, sika deer hunting still persisted when pig domestication and husbandry had become intensified. The reason for this phenomenon will be explored in detail in Chapter 8, not only from a subsistence perspective, but also from an ecological behaviour angle.

CHAPTER 7
CONTEXUAL PATTERNING: INTRA-SITE ANALYSIS OF FAUNAL REMAINS

Understanding the processes of site formation is an important aspect of tracing past human behaviour. The utilization and abandonment of animal bones can be reflected in the spatial patterning of animal bone distribution. The relationship between human beings and their garbage can vary between communities in terms of their abandonment behaviour. Needman and Spence (1977:77) proposed that "refuse or garbage has become a widely appreciated category of archaeological evidence significant for many aspects of social organization." In this section, the spatial distribution of faunal remains from Wayaogou will be analyzed to explore the deposition processes of animal bones, human abandonment behaviour, and possible attitudes towards the animal discards, and furthermore to shed light on aspects of social organization during the Yangshao period.

7.1 Research Questions

It has been widely appreciated that the communities of the Yangshao period lived a sedentary life style, with millet cultivation and pig domestication playing an important role in the subsistence system. However, the linkage between refuse disposal strategies and residential occupations of the Yangshao people has seldom been addressed before. In order to understand the deposition processes of faunal remains, the following issues will be explored: first, do the distributions of faunal remains represent a real spatial pattern or are they mainly the result of some taphonomic processes? If there does seem to be real spatial patterning of

deposition, how and why were animal bones deposited in certain features? Do there seem to be rules for the disposal of materials? Is there any specific treatment of animal bones or the remains of certain animals at the site? Was the disposal of animal bones related to the social organization of this community?

As part of this enquiry we need to ask whether the distribution pattern of faunal remains is different between different features, such as open living surface, pits, ditches and house foundations. Are there variations between pits and how might taphonomic processes vary between these pits? How might animal bone deposition relate to human activities, such as consumption and tool production?

Pigs and sika were the most heavily exploited animals at the site, although pigs were mostly domesticated whereas sika deer were hunted. It is of interest to see whether pigs and sika deer were utilized in the same way. Are there any distribution differences between sika deer and pig remains at Wayaogou? Does the proportion within each feature follow the same pattern? Also, the relationship between people and dogs in ancient China is quite controversial, and the consideration of the deposition patterns of dog remains could suggest a special relationship between the dog and human beings. Was there any evidence indicating they were consumed at the site?

7.2. Theory and Approaches

Ethno-archaeological studies suggest that there is a link between residential strategies and discard behaviours. Several categories of refuse have been defined by Schiffer (1976): primary refuse refers to the intentional discard of items at or

near the end of their use-life, in their locations of use; secondary refuse is the discard of bones in areas other than where they were used. Not all bones will be discarded where they were first used. Many specimens, especially in areas which are inhabited continuously, may be swept up and deposited in a disposal area distant from the activity area where they actually become waste. By evaluating different taphonomic effects on bones from different contexts, the depositional processes of animal bones at the site will be explored.

There were five types of features recovered at the site: open living surface, house architecture remains (F), pits (H), ditches and burials (adult burials M and child burials W). The term “pit” is widely-used in archaeological excavations in China, but their attributes vary according to their functions: ash pits, whose function is mainly for disposal of rubbish; storage pits or hoards used to store grain or other items. Also some pits may have been used for dwelling. It is difficult to define the exact function of excavated pits as they may have had different usage at different stages. For example, some pits may have been used for storage when they were first built, but may have gone on to be used for dumping rubbish when they were abandoned. In order to understand human residential strategies and the depositional processes of faunal remains at the site, bone distribution patterns and density variations between these features will be explored. Spatial analysis methods will be applied in this chapter and ArcView GIS Version 9.3 will used to construct gray scale density plots. Bone distributions in this analysis are presented as both areal densities (artifacts per square metre) and volumetric densities (artifacts per cubic metre).

Spatial analysis was carried out on the basis of density of bone fragment per locus, relatively density per grid square and number of bones per grid square. Volumes for individual features were estimated using feature measurements recorded during the excavation. Feature volumes and number of bones fragments were combined to provide estimates of volumetric density of faunal remains for each feature and density per 10×10 square metres. At Wayaogou, there was much variation between these features in terms of bone density, ranging from 0-284 fragments per cubic metre. The richest feature was H199 (pit), from which 1310 fragments of bones were recovered.

7.3 Taphonomic variations between different features

Two indexes are used to evaluate the abundance of the faunal remains from different context types, NSP and NISP. NSP is the number of all specimens in an assemblage or collection, including those that are identified to taxon and those are not identifiable (Lyman 2008). NSP has been used by several archaeologists (Grayson 1991; Stiner 2005: 81-112). NISP is the number of identifiable specimens, which has been widely used in zooarchaeological analysis.

About 23,400 (NSP) fragments of animal bones were recovered from Wayaogou in total (Tab. 7.1), of which about 80% were from those archaeological features termed pit (H) and 13% were located in ditches (G). Only 5% were recovered from house foundations (F) and fragments recovered from open living surfaces (the space between the structures), and the fill of burials (M) made up less than 2% of the faunal remains in each. In total, 4,526 specimens can be identified to taxa or species (eg. NISP), of which 79.5% were recovered from pits whereas

10.3% were from ditches. Identified specimens from house remains and open living surface only occupied around 5%. Very few animal bones were recovered from burials.

The proportion (percentage) of identified *versus* unidentified bones can be plotted to compare the intensity of fragmentation of bones recovered from different types of features (Fig. 7.1). The identified to unidentified ratio shows similar pattern for faunas recovered from houses, ditches and pits. Fragments recovered from open living surfaces show a high proportion of identified specimens, which is probably due to recovery bias because small fragmented (unidentified) bones were more likely to be ignored if they were in the very extensive open living surfaces at the site. It is quite interesting to notice that similar ratios of identified and unidentified were calculated for bones recovered from house remains and pits, which probably suggests that certain house remains witnessed the same taphonomic process as the pits.

Context types	**NSP**	**NSP%**	**NISP**	**NISP%**
House	1227	5.2%	226	5%
Ditch	3048	13%	466	10.3%
Pits	18,824	80.4%	3596	79.5%
Open living surface	262	1.1%	202	4.5%
Burial	39	0.17%	36	0.8%
Total	23,400		4526	

Tab. 7.1 Number of all specimens (NSP) and number of identified specimens (NISP) from different contexts at Wayaogou

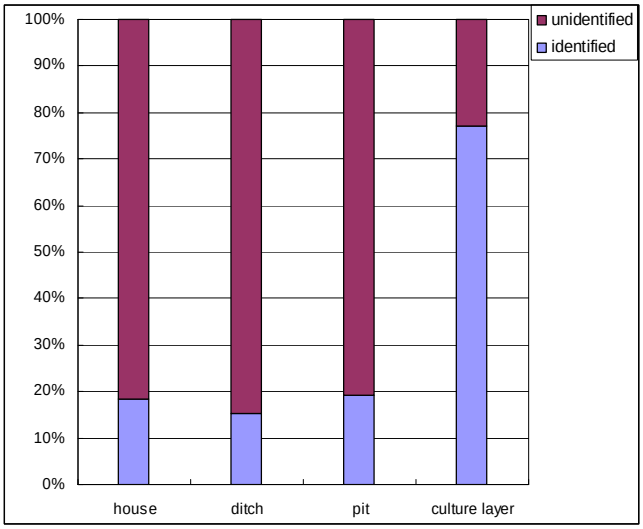


Fig. 7.1 Ratio of identified skeleton parts to unidentified fragments of mammal bones from different contexts

7.3.1 Weathering stage

Weathering is an important taphonomic process, in which the original microscopic organic and inorganic components of bones are destroyed by physical and chemical agents operating on the bones *in situ,* either on the surface or within the soil zones (Behrensmeyer 1978: 153). Weathering stages are common criteria used to record the preservation conditions of animal bones at sites. In the York system, four weathering stages are defined, and each identified fragment is assigned to a weathering stage: excellent, good, fair and poor. The descriptions of each weathering stage are as following: excellent: majority of surface fresh and even slightly glossy; highly localized flaky or powdery patches; good: lack fresh appearance but solid; very localized flaky or powdery patches; fair: surface solid in places, but flaky or powdery on up to 49% of specimen; poor: flaky or powdery over 50% of specimen (Harland *et al.* 2003).

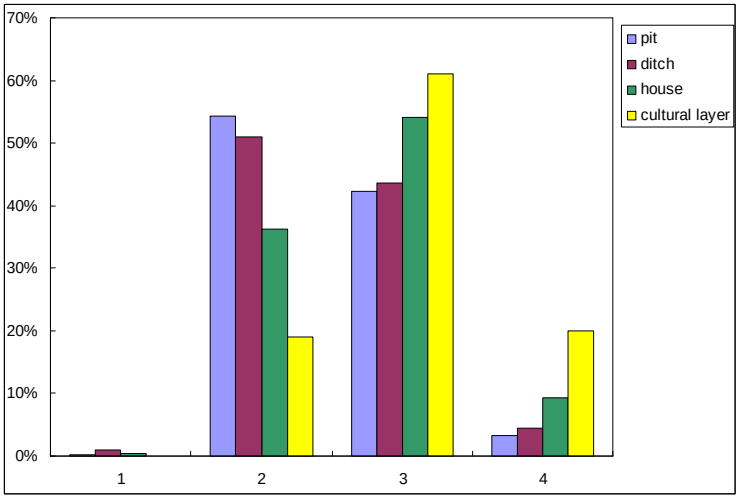


Fig. 7.2 Frequency distributions of percentages of bones per weathering stage in the assemblage, shown by different contexts (1: excellent; 2: good; 3: fair; 4: poor)

The percentages of specimens (NISP) of different weathering stages from four types of features at Wayaogou are plotted in Fig. 7.2, suggesting that bones from house remains and cultural layers were more weathered compared to those recovered from pits and ditches. This probably implies that bone from houses and cultural layers experienced a relatively long exposure period compared to those from pits and ditches. Bones recovered from pits preserved best at the site; with a higher percentage of bones with weathering stage "good" (stage 2). Previous research suggest that the differences in the bone assemblages recovered from enclosure features are considerable (Maltby 1981, cited in Hill 1995), largely due to different preservation conditions of bones in closed and open features. Bones in buried features, such as pits, were largely protected from the effects of gnawing, trampling, weathering, compared to those in open features, such as cultural layers, house foundations. Weathering stages of bones from pits, ditches, house remains and cultural layers at Wayaogou suggest that bones which were deposited in closure features, such as pits, preserved better than those from open features, such as house remains and cultural layers. This pattern may also relate to being quickly

buried in the pits.

7.3.2 Carnivore gnawing, rodent gnawing and root etching

Carnivore gnawing is another agent that could influence the preservation of bones at the site. The percentages of animal bones with carnivore gnawing from different contexts were plotted in Fig. 7.3. It suggested that in general, in all contexts, carnivore gnawing marks made up less than 2%, which is quite low. However, carnivore gnawing marks were more frequently present on bones recovered from pits and houses. Dogs were the main domesticates of the Yangshao communities and they were probably close companions in humans' daily lives. Animal bones, most of which represented leftovers or rubbish from human consumption activities, could have been very attractive to carnivores. Because dogs probably lived close to humans, they would have had opportunities to feed on these bones after they were used by humans. Pits and houses were the features that related to human's daily life.

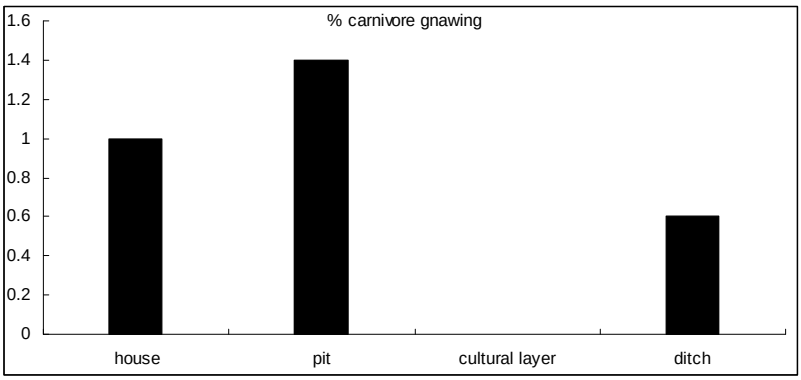


Fig. 7.3 The %NISP of faunal remains with carnivore gnawing from different contexts. NISP values: house (293); pit (5224); ditch (540); open living surface (447)

7.3.3 Burning

Burning is a common phenomenon in archaeological assemblages and it results

from excessive heat that modifies and damages the heated objects. Burnt bones made up a high percentage of faunal remains at Wayaogou. About ten percent of bones (NISP) were burned in the whole assemblage. The percentages of burnt bones (NISP) from different contexts are plotted in Fig. 7.4. Since the burnt bones can preserve better compared to the unburnt fragments (Lyman 1994: 391), these proportions may not represent the real patterns at the time when the bones were deposited. The idea that cooking will produce burnt bones is too simple and unrealistic, and the agents that may lead to burnt bones have been summarized by researchers (Buikstra and Swegle 1989, David 1990, James 1989). Apart from cooking, other agents relating to human's activities are the disposal of food waste, using bones as fuel, and also, bones may occasionally become burned by natural fire. However, it is difficult to determine which agents contributed most to burnt bones in archaeological assemblages.

The percentages of burnt bones for the main species at Wayaogou were counted in Tab. 7.2. A relatively high percentage of burnt bones have been observed for musk deer (22.2%). There were more sika deer bones burned than pig bones at the site. However, as mentioned above, bones can be burned at any taphonomic stages and it is difficult to determine whether bones were burned accidentally or intentionally.

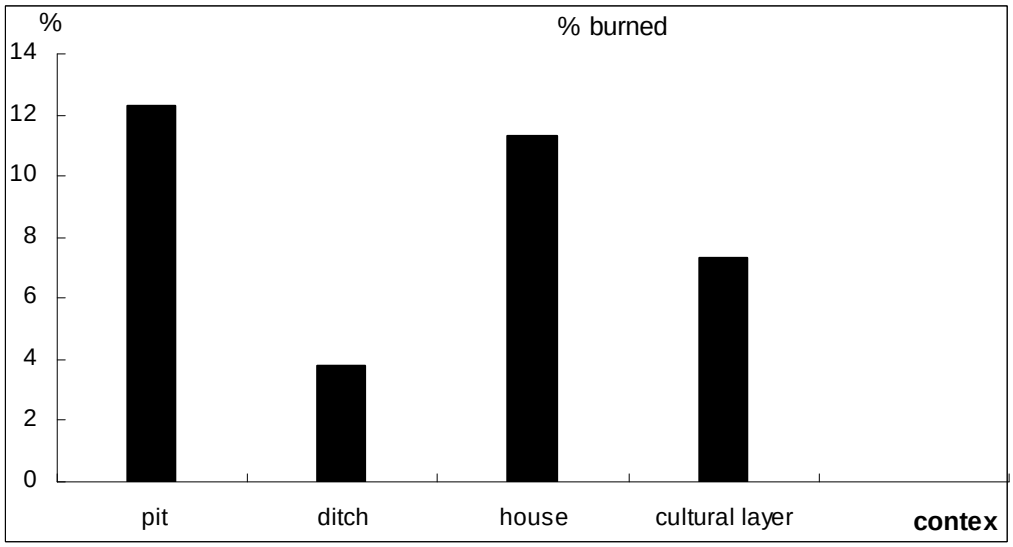


Fig. 7.4 The percentages of burnt bones (%NISP) from different contexts; NISP values: house (293); pit (5224); ditch (540); open living surface (447)

	sika	**pig**	**roe deer**	**musk deer**	**water deer**	**badger**	**dog**	**hare**	**total**
Burned	331	160	14	6	4	4	5	2	693
NISP	2947	2338	154	27	52	63	84	53	6094
%burned	11.2%	6.8%	9.1%	22.2%	7.7%	6.3%	6.0%	3.8%	11.4%

Table 7.2 The percentage of burnt bones for various species at Wayaogou

7.4 Contextual analyses of different types of features

7.4.1 Investigation of house foundations

At least 16 features that have been determined as architecture remains were recovered from Wayaogou, which can be classified into two types according to their shapes: round ones and rectangular ones. They were semi-subterranean or on ground level. Spatial distribution analysis suggested that these houses were not clustered in one area but were spread evenly across the site.

Spatial analysis of faunal remains from house remains shows many variations in terms of NISP and NSP. Faunal remains were absent in most of them (12 out of 16). One sika deer phalanx was recovered from architectural feature 6 (F6). Two house remains (F1 and F3) were recovered with large quantities of bones, probably meaning that they had been used to dump garbage after they were abandoned, or that garbage was not cleaned up, but these were rare cases. Houses or architectural features were places where daily activities are likely to have taken place, and the lower density of faunal remains in most house remains suggests that probably rubbish was cleaned up frequently from the houses. However, the depositions in one architectural feature (F16) seem different from that of the others. It was a typical rectangular grass tempered brick structure, measuring roughly 5.4×4.15m. Eighteen fragments of bones were recovered from the infill of the floor of this house and all of them were identified to species level, which included six fragments of pig bones, ten fragments of sika deer, one rabbit pelvis and one roe deer scapula. The house was located inside a round ditch in the northeast part of the excavation area. The F16 structure was located at the mouth of the ditch, and the internal features included a heavily trampled floor, an oven and a hearth. Its special location and contents suggests that this house may have had a different function for the community. The social meaning of the house, the ditch and other features inside the ditch will be discussed in detail below.

7.4.2 Investigation of pits: taphonomic variations

Pits were the most common features at the site, and contained the highest proportion of finds, such as animal bones and pottery sherds. There were three types of pits in terms of shape: round/oval, rectangular and irregular ones. For the

ones with oval or round opening, the diameter of the bottoms was always smaller than that of the opening, which made these pits shaped like a bag. This type of pit has been widely called “bag-shaped” in China. The bag-shaped pits were the most common ones at Wayaogou (78.5%). The other type was straight sided, with rectangular mouth and bottom, which made up only 11%. The rest had an irregular shape. Animal bones were particularly associated with the bag-shaped pits at Wayaogou.

Some pits were well constructed and the wall and the foundation had been carefully furbished with small rocks. Platform or steps were recovered at some pits, which probably suggest that dumping rubbish was not the primary purpose since steps are not necessary for rubbish bins. Rather steps are very important for hoards when people try to put material into storage or extract it, and platforms can be used for placing pottery vessels or other objects. Completed pots were recovered from the platform or the base of some pits, for example, H48, which suggests that the pit was still used as a hoard. It also implies that some pits were not built for storage in the first place.

Pits were the most common features where animal bones accumulated. In order to evaluate the depositional variation and depositional paths of these pits, some taphonomic processes, such as bone fragmentation, carnivore and rodent attrition and burning intensity will be explored. Since most pits were bag-shaped, and most faunal remains have been recovered from this type of pit, it seems meaningless to group them according to their shape. In addition, the structure of these pits suggests that many functions were involved in the deposition processes of these

pits. Therefore, there seems no point in grouping them according to their structure. However, the bone density in each pit might reflect human discard behaviour, since there is much variation in bone density deposition between these pits. This may reflect different deposition and taphonomic processes. Thus, bone density has been used as a criterion to group these pits in this analysis.

Bone density in each pit was calculated by dividing the NISP by the exact volumes. The volume of pits was calculated using the pit size recorded during the excavation. If more than one parameter had been recorded for the diameter of the pit, the largest and the smallest was used to calculate the area size of the pits, which assumes the pit is elipse-shape at the opening or bottom. If more than one parameter had been recorded for the depth of the pits, the average was used for calculating the volume of the pits. The density of the bone fragment in pits varied from 0 to 53 in terms of number of identified specimens (NISP) per cubic metres (see appendix 7.1). According to bone density, these pits were grouped into three categories: group 1: NISP/m^3<1 (bone remains were rare or absent); group 2: NISP/m^3 1-10 (low density of bone remains); group 3: NISP/m^3>10 (high density of bone remains). Different taphonomic factors will be investigated to explore the deposition processes of these pits.

Bone fragmentation

The ratio of the identified and unidentified bones from three groups of pits is shown in Fig. 7.5, which suggests that there is a trend for pits with a higher density of bones fragments to have higher fragmentation (more unidentified fragments).

The relative proportions of sika and pig bones (NISP) for three groups of pits were plotted in Fig. 7.6. While ratios are quite similar there is a slight pattern showing more sika deer remains in high density pits.

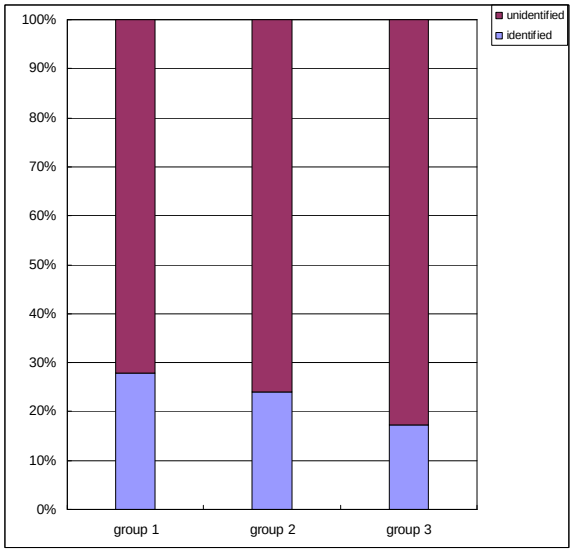


Fig. 7.5 Ratio of identified skeleton parts to unidentified fragments of mammal bones for three groups of pits at Wayaogou; the pits have been assigned to three groups according to the density of bones (NISP/m^3) recovered.

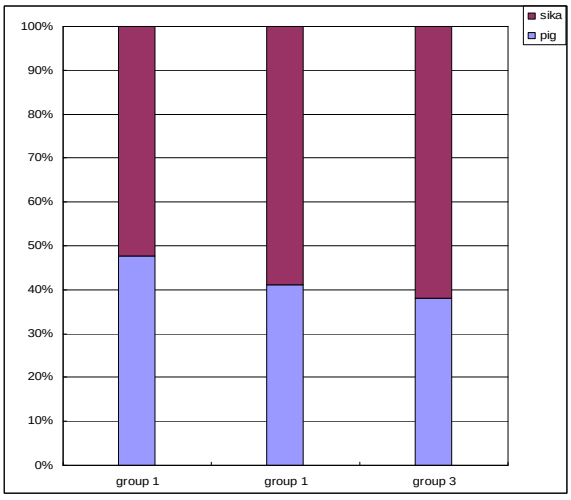


Fig. 7.6 The relative proportions of sika deer and pig for three groups of pits at Wayaogou

Weathering

The frequency distribution of percentages of bones per weathering stage in the assemblages of three groups of pits is plotted in Fig. 7.7. It shows that assemblages with lower densities of bones were more weathered (group 1) compared to those with higher density of bones (group 3), indicating that bones recovered from pits with lower density of bones probably experienced longer exposure durations before they were deposited or buried.

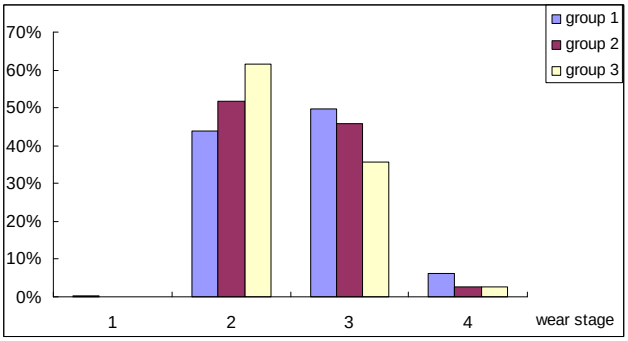


Fig. 7.7 Frequency distributions of percentages of bones per weathering stage in the three groups of pits (1: excellent; 2: good; 3: fair; 4: poor)

Carnivore and rodent attrition

The percentages of bones with carnivore gnawing and rodent gnawing were calculated for each group of pits (Fig. 7.8). It is interesting to note that bones recovered from pits with a high density of bones have a higher percentage of carnivore gnawing marks, although overall percentages are generally very low (less than 2.5%, Fig. 7.8), lower than those of some Natufian faunal assemblages (about 5%, Davis 1987: 148). The effect of rodent gnawing, however, is similar across the three groups of pits at Wayaogou. Different species of rodents were found at the site, including bamboo rat, zokor, tundra vole and brown rat. All these species dig underground burrows to store seeds and roots. Considering the

taphonomic effects that carnivores and rodents can cause on bones, carnivore and rodent gnawing may differ in terms of timing. Most carnivore attrition most likely occurred before the bones were buried, whereas rodents can gnaw the bones before or after their deposition because of the digging behaviour of the animal.

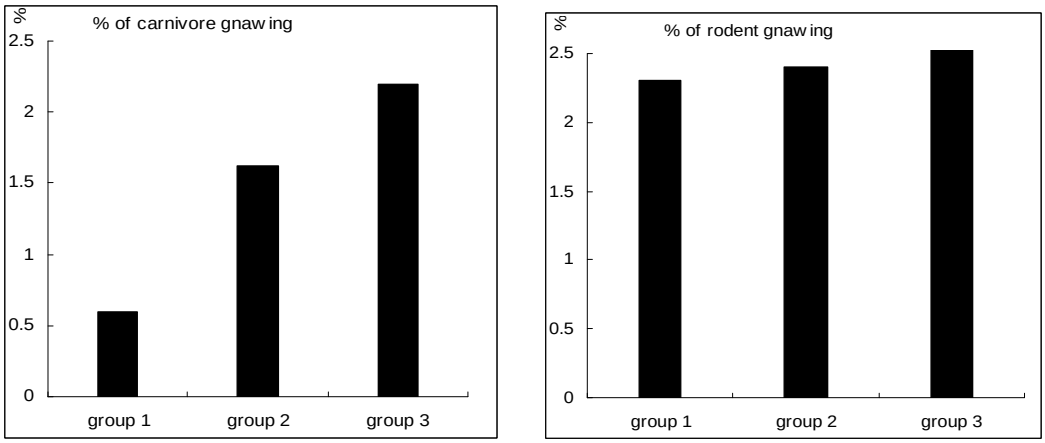


Fig. 7.8 The percentage of faunal remains with carnivore gnawing and rodent gnawing from the three groups of pits at Wayaogou

Burning

Burnt bones make up 11.4% of the faunal remains recovered from pits. It is interesting to notice that a high percentage of burnt bones were recovered from group 2 pits (Fig. 7.9). However, as mentioned above, accidental natural fire and human intentional activities were all factors likely to produce burnt bones at the site, so it is difficult to determine the timing and agents that caused the pattern of burnt bones.

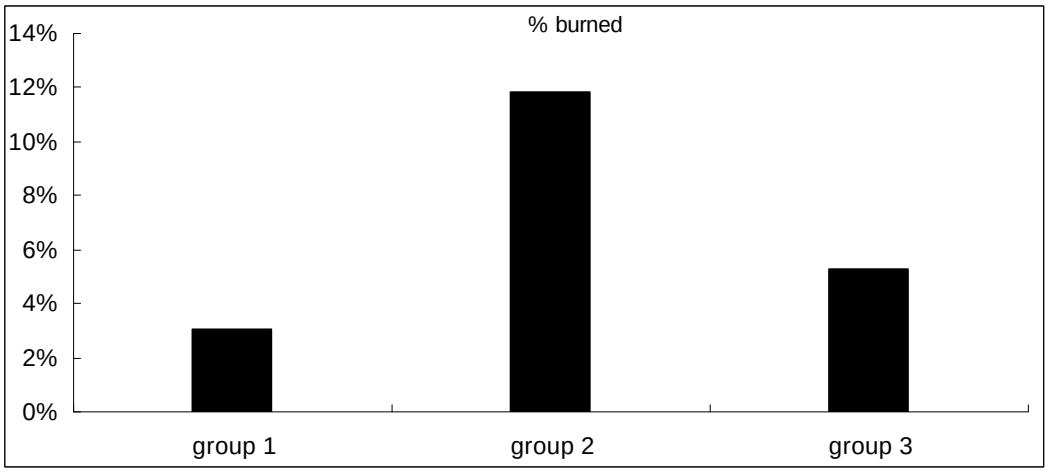


Fig. 7.9 The percentage of burnt bones recovered from the three groups of pits

Discussion

Various taphonomic processes were drawn together to explore the depositional variations between the pits (Tab. 7.3). In group 1, in which the bone density is relatively low, the bones were less fragmented, more weathered, with very little dog gnawing present, whereas in group 3 the bone density is quite high, bones were more fragmented, less weathered and more frequent dog gnawing present. Group 2 pits show roughly a pattern in the middle for these taphonomic effects, between group 1 and 3. Since there were a higher percentage of bones with weathering stage 1(excellent) and 2 (good) in pits group 3, it is reasonable to assume that material bone experienced a relatively shorter duration of exposure, probably deposited soon after being discarded. Probably these bones were the refuse of daily consumption activities, which were cleaned up on a regular basis by people. In this group, some pits were well constructed with platforms or steps, which suggest that probably they had been used for storage before being used as rubbish pits. From the other point of view, the abandoned pits were more easily selected as rubbish areas, because of their solid structures or particular locations. People had already got used to using these pits in their daily lives.

pit type	density	taxa (pig/sika)	burning	weathering	fragmentation	dog gnawing	rodent gnawing
group 1	××	91.4%	×	×××××	××	×	××××
group 2	×××	69.8%	×××××	×××	×××	×××	×××××
group 3	×××××	61.3%	××	××	×××××	×××××	×××××

Tab. 7.3 The various taphonomic signatures on the faunal remains for the three groups of pits at Wayaogou

In contrast, in some pits, bones were absent or the density was quite low, which means they only occasionally got incorporated into pits. The bones were relatively more weathered in these pits, indicating longer exposure before deposition, different taphonomic processes compared with those from group 1. Bone remains may have arrived unintentionally in these pits by being eroded or washed in, or occasionally thrown in by people; whichever the built-up was probably a slow process. A lower percentage of dog gnawing on these bones suggests dogs were not particularly interested in these less fresh fragments or they had little opportunity to gnaw them. Most of these pits had no platform or steps, or well-made base, suggesting that they were built with less effort.

7.4. 3 Investigation of the Ditch

A round ditch in the northern part of the excavation area was recovered, which was about 80 m long, with a diameter of 26 metres in the outside loop (Fig. 7.10). The width of the ditch varied from 1 metre to 2.5 metres and a high density of bones remains were recovered from the ditch. The outlet of the ditch faced to the west. A house foundation (F16) was recovered inside the ditch, close to the outlet. Animal remains were recovered from the rammed earth of the floor and all of them can be identified to species, suggesting that these bones may have been

buried there on purpose. It is possible that these bones were buried there after certain ritual activities, which may have related to the building process of the house. Large quantities of child burials were recovered from inside the ditch area and two of them were buried with high quality objects such as jade. Animal bones were present in small quantities in the pits inside the ditch. As mentioned above, taphonomic analysis suggests that the bone assemblage from the ditch was more weathered than those from the pits. Probably animal bones were not deposited in the ditch in a fresh condition, but instead were left on the ground for a long period before they were thrown or eroded into the ditches. Carnivore gnawing was present in low percentages, suggesting that the bones were not as attractive to carnivores; probably because they were not fresh or this was not an area where dogs were usually present. In conclusion, the taphonomic analysis suggests that the deposition of faunal remains in the ditch was a slow process.

The ditch stands out among other features at the site and therefore interpretation of its social meaning should be attempted. It is difficult to interpret it as a real defending barrier because it did not surround the whole settlement. Child burials with rich artifacts suggest high social status, or special treatment of these children. All the adult burials were concentrated on the western part of the excavated area. The house remains within the ditch showed different architecture from that elsewhere on the site. All information hints that this is a special locus for the community; probably it was for public activities rather than household activities. The boundary, or the threshold, is an important idea and conception in many cultures. The model of rites of passages was drawn from a discussion of the symbolism and ritual surrounding threshold in many cultures (Van Gennep's 1960), and he has also suggested that the liminal nature of the boundary, a space

between, a non-space, as the reason why it was an appropriate place to bury infants in some societies. The ditch seems a good medium for the community, to symbolize ideas about a boundary or threshold, so perhaps the main purpose for building up this ditch within the settlements was to give the area a special social meaning. Similar observations and interpretations have been made for some Iron Age sites in Britain (Hill 1995).

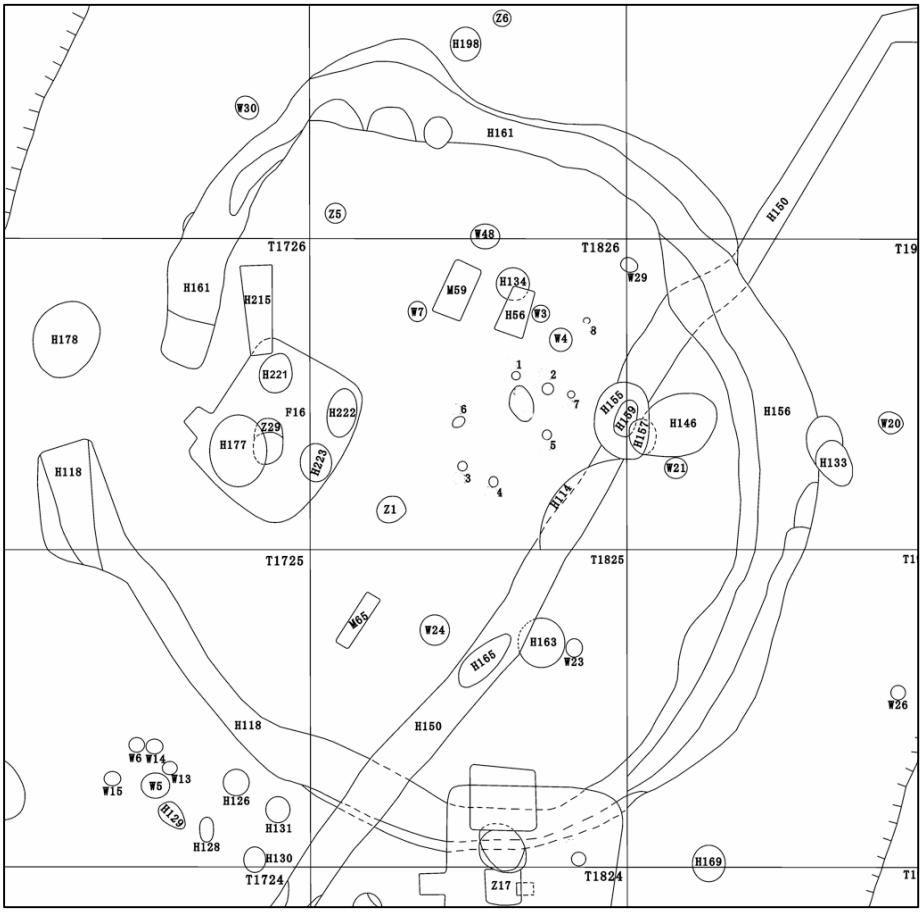


Fig. 7.10 The plan of the ditch at Wayaogou and the internal features (the ditch measures about 26 metres across)

It is very interesting to notice that a house foundation is situated on top of the ditch, which may imply that the ditch may have been abandoned after a period of use, and a house was built on its top when the existence of the ditch has been neglected and filled. Another possibility is that there was some specific relationship between the house and the ditch or there was a specific function of the house. However, a hearth was recovered

inside the house, suggesting that probably the house weas related to human daily life. Without analysis of other finds from the house and the area, it is difficult to interpret at this stage.

7.5 The social implications of the spatial distributions of the features

The social organization during the Yangshao period has been debated since the first site was found in the Yangshao village, Henan Province. Previous studies on settlement pattern were mainly based on data from several well reported sites in the Wei River valley, including Banpo (Institute of Archaeology, CASS 1963) and Jiangzhai (Xi-an Banpo Musuem *et al.* 1988). The traditional interpretation of the Yangshao community holds that it was a matrilineal organization which practiced "pairing marriage", and small-and medium-sized houses were used for the members of matrilineal clans, while the "large house" was for the chief or secret social groups. This interpretation resulted from the influence of Soviet archaeology in the 1950s, largely based on architectural remains and burials from a few sites, such as Banpo, Jiangzhai and Yuanjunmiao (Yan 1989; Zhang 1985). However, this interpretation has been extensively criticized by scholars inside and outside China (Wang 1986; Pearson 1988), and they point out that the burial patterns in the Neolithic China can not be used to detect some issues of the communities, such as the kinship and social status of these dead people. Instead, different burial patterns conferred information related to other aspects of the social organization, such as the division of labour and the size and nature of work groups (Pearson 1988). Later, based on the studies on the spatial relationship of each residential sector, Lee (1993 cited in Liu 2004) proposed that Yangshao archaeological features could be defined as many small clusters, each cluster

comprising domestic features including houses, hearths, and pits, and probably functioning as a single socio-economic unit or household. However, this proposal was not well supported by detailed spatial analyses of all the features and archaeological remains recovered from the sites. In this section, the spatial association of archaeological features and their contents from the Wayaogou settlement will be discussed, to assess the social function of the features, how they related to each other in terms of function, and whether any information related to social organization can be inferred.

As mentioned above, the spatial distribution of faunal remains suggests there is much variation in the density of faunal remains in different contexts. The range of densities for pits was 0 to 284 specimens per cubic meter. The richest pits were H199 (*ca* 284 per cubic metre), H94 (*ca* 210 per cubic metre), H179 (*ca* 206 per cubic metre) and H 29 (*ca* 193 per cubic metre). The moderately rich pits include H100 (*ca* 147 cubic metre), H118 (*ca* 143 cubic metre), H219 (*ca* 139 cubic metre), H238 (*ca* 137 cubic metre) and H4 (*ca* 133 cubic metre). The NS density maps were constructed using ArcGIS Version 9.3. The results suggested that there was no cluster for the pits with high density bones (Fig. 7.11), which suggest that probably there was no specific area for rubbish disposal at the site.

However, if we relate pits to other contexts, such as house remains and burials, we notice that pits with high density of faunal remains were closely associated with areas where child burials were clustered (Fig. 7.12). Previous observations suggested that it was a common phenomenon that children were put in jars buried around the dwelling area during the middle Neolithic (Pearson 1988). Child burial

pattern at Wayaogou suggests that children were not buried in proper burial areas in the Neolithic and most of them were buried in rubbish areas. Spatial analysis suggested that there is a close association of house remains, the pits and the children's burials, indicating that they may function as a basic social-economic unit at the site (Fig. 7.12). Also, this may reflect consumption patterns that were mainly taking place in households. Although the deposition pattern of the rubbish can provide information for the consumption pattern in the community, it is difficult to infer the social role of the members of each household and their relationships.

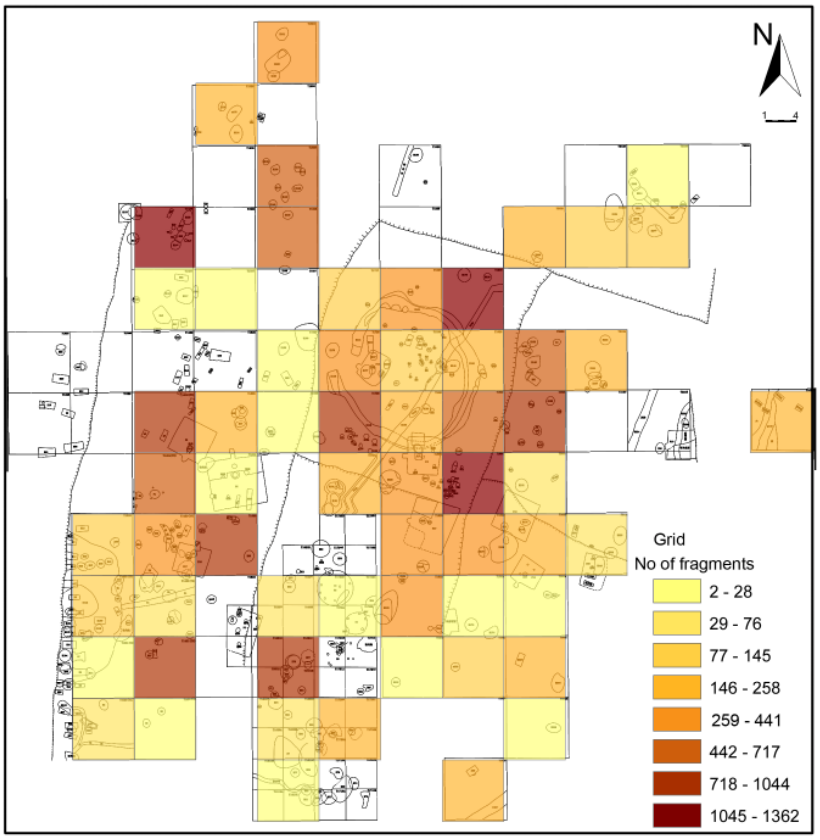


Fig. 7.11 Bone density for each grid at Wayaogou (each grid measures 10 m^2)

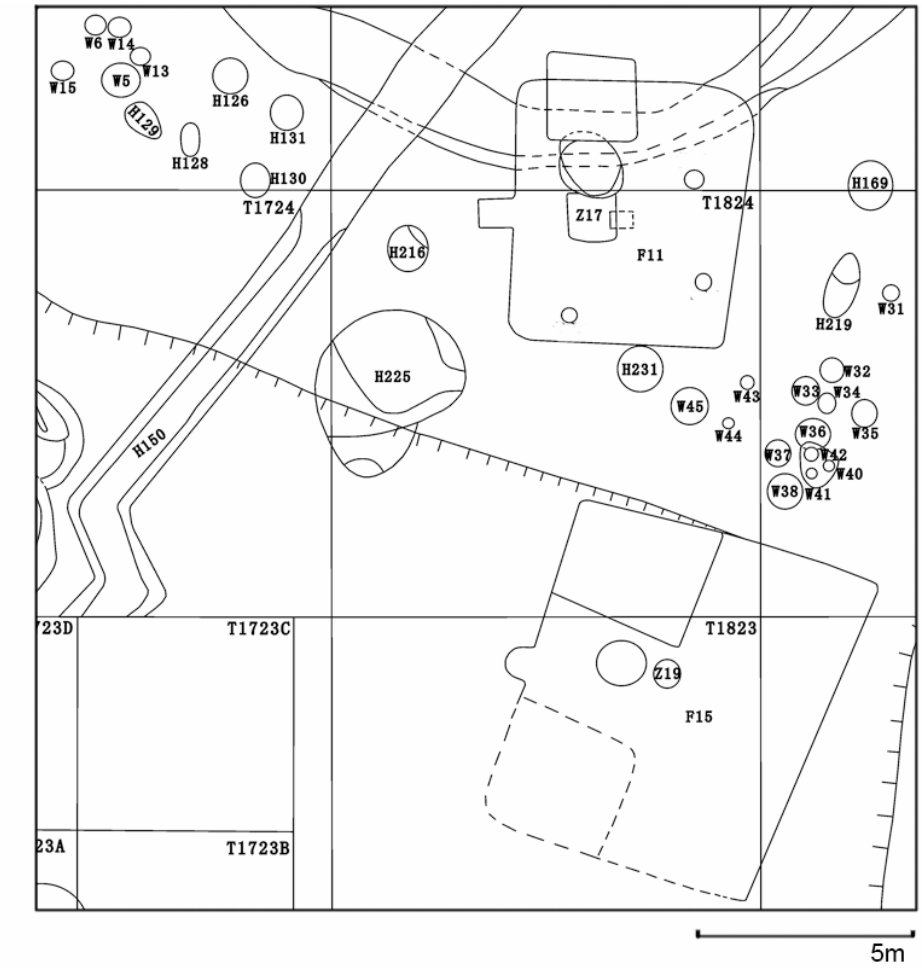


Fig. 7.12 An example showing the association between the house remains (F15, F11), the child burials (W) and pits with high densities of bones (H219)

7.6 Discussion and Conclusions

This section attempted to explore the variations of the deposition patterns of different features and paths of the animal bones deposition at the site. The distribution and relative density of materials were plotted, to infer activities and practices at the site, and maybe also some social meanings of the deposition.

The absence or low density of animal bones from most house remains suggests

that probably the living areas were cleaned up on a regularly base, and almost no rubbish was accumulated in the house where the animals were first used, either for eating or producing tools. These houses have been used for a long time period and the waste was regularly cleaned from the house, which coincided with sedentary life style. Pits, which were used for storage when they were built, were the places where most rubbish accumulated. Because of their good location (probably close to the houses), well constructed structures and a long relationship with human beings, they were the first choices for humans to dump their rubbish. Probably these pits were filled more than one time, but in a relatively short time period. The high density of bones from these pits, and the taphonomic information of the bones, suggest this. In contrast, bones recovered from pits with less dense accumulation may have experienced longer exposure and were moved into these pits slowly. The integrated analysis suggested that the inhabitants of Wayaogou were trying to make the best use of the facilities they had built: they were trying to keep the house clean, so they were able to live there for a relatively longer time; some pits were well built and used as storage first and used for dumping rubbish later.

Social meanings were implied for some special features and special treatment of animal bones and animals. The ditch may indicate that boundary or the threshold was an important idea and conception for the community. The special deposition of animal bones in the house inside the ditch suggested that they may have ritual meanings; probably this house, associated with the ditch, was the locus of ritual activities. Special treatment for dog was practiced at the site, as whole dog skeletons were recovered from pits. The absence of cut marks on dog bones

suggests dogs were probably not involved with human diet, and there was a special relationship between humans and dogs; dogs were companion for humans. The distribution patterns of features and their contents may hint of the social implication of the settlement. It seems that the dwelling places were closely associated with pits with high density materials, which probably made up the basic social-economic units. It also suggests that rubbish was dumped not far from the living areas.

This analysis was based on the hand-collected materials of one site and there may be some bias for the propositions of some issues. However, it is worth trying to explore the relationship between the rubbish and human behaviour and selections at the site. Although some issues brought up remain as hypotheses and need to be tested in the future archaeological excavations and research, and some remain as questions, they inspire us to think about questions other than the typology of the pottery artifacts at the site, such as the site formation processes and human behaviour.

CHAPTER 8
DISCUSSION AND CONCLUSIONS

This project has investigated diverse aspects of animal subsistence strategies of the Yangshao period in the Wei River valley, with a case study on animal utilization patterns of the Wayaogou community. The study has mainly focused on human interaction with two species: pig domestication and sika deer hunting, since pig and sika deer bones make up about 80% of the faunal remains. Archaeological data from other sites in this region were used for comparison, to investigate variation between sites, understanding how animal utilization patterns changed in different phases of the Neolithic in this region and how this change related to the evolution of human societies. In this chapter, firstly, the faunal analysis results from previous chapters will be summarized. Based on this, animal resource exploitation patterns, and the interactions of human and animals and the consequence of this relationship for both human communities and their environment, will be further discussed.

Various issues concerning animal subsistence of the Yangshao period have been explored in previous chapters of this thesis:

Chapter 4 focused on the analysis of the range and relative taxonomic abundance of animals at Wayaogou, suggesting that although more than 30 mammalian species were recovered, the deer taxa and pigs were most commonly utilized at the site, and they contributed a large proportion to the subsistence economy. Various species present at the site pointed to a mixed habitat of grassland, woodland, scrub and bushy areas, and some types of freshwater habitats. The

taphonomic habitat index (THI) of small mammals suggests that grassland or hillside shrub/grassland were abundant and close to the site. However, the large percentage of deer recovered suggests that human hunting activities mainly occurred in the forests and woodlands which seemed a little further away from the site.

Chapter 5 used different lines of evidence to document the process of pig domestication and husbandry strategies at Wayaogou and other sites in the Wei River valley. Morphological evidence from teeth and postcranial measurement data from pig remains suggest that the size reduction of pigs continued from the early Neolithic to the late Neolithic in this region, and Wayaogou fitted well into this trend. Second, the kill-off patterns suggest that most pigs died before they reached two years old at Wayaogou, which is a typical age structure pattern for domesticated populations. The interpretation of domesticated status of pig at Wayaogou was enhanced by the linear enamel hypoplasia analysis (LEH); a high frequency of the occurrence of LEHs on the pig teeth from Wayaogou suggested a greater pressure experienced by the domesticated population when humans controlled them, compared with wild boar in this region. The process of pig domestication was documented in a broader geographic context by recording the species spectrum change from sites of different periods in the Neolithic (chapter 4). The results suggest that the relative proportion of pig remains increased from the early phase to the late phase of the middle Neolithic, and correspondingly deer remains decreased (chapter 4, Fig. 4.4). This pattern probably accompanies the pig domestication process and intensification of pig husbandry throughout the Neolithic in this region. Pig husbandry strategies have been hinted at with the

evidence from the linear enamel hypoplasia and tooth wear stage patterns of Wayaogou and other Neolithic sites (such as Quanhucun and Lingkou) in this region. The results indicate that most pigs were born in the spring, probably between April to May, and the practice of single farrowing was common, and double farrowing was absent or rare during the Neolithic in this region.

The relative proportion of different species at the site indicate that although pigs most likely had a domestic status at the site, deer hunting still played an important role in the subsistence system, since high frequencies of deer remains were recovered. In chapter 6, deer hunting strategies were explored in detail: the kill-off pattern of sika deer suggests that selective hunting strategies were practiced at the site and sika deer did not become prey until they were adults or sub-adults, when they had reached their maximum body weight. This age structure also indicates that conservation or the reproduction of the species, were a part of human consideration since relatively small proportions of sika were killed between two years old and four years old, which is the prime reproduction age for the species. Evidence from skulls and antlers suggest that large numbers of sika deer were hunted during the winter time when the species tends to congregate and more males have been targeted since they are always at the fringe of the herds during the aggregation season. The raw materials for bone tool manufacture are mainly from the sika deer elements whereas the body parts of pig were seldom used. Taphonomic analysis suggested that bone tool production had significant influence on the frequency of skeletal part representation of sika deer. Hence, sika deer, unlike pigs, were not only exploited for the provision of meat, but also for the antlers and bones to produce bone tools.

Morphometric studies suggest that there was no pronounced size change of sika deer during the middle Neolithic which is consistent with other lines of environmental evidence, such as pollen and results of archaeobotanical analysis (see chapter 2). However, size variation of sika deer can be observed from sites of different periods, seemingly to show sika deer getting smaller in the late phase of the Yangshao period compared with the middle phase of the Yangshao period. The size variations of sika deer may reflect hunting pressures in the later phase.

Contextual analysis at Wayaogou was undertaken in chapter 7 to investigate taphonomic processes and variation between different groups of archaeological features. The results suggest that humans lived a sedentary life style and that food storage was practiced at the site, as some pits were built with huge effort. Rubbish in the dwelling areas was cleared out on a regular basis and dumped into pits nearby. This combined evidence points to a proposition that the site was occupied for a relatively short time period before it was abandoned, probably just a few centuries. Spatial analysis of different types of features suggest that the house foundation, the pits and the child burials seem closely associated in space, suggesting that they probably comprised a basic social-economic unit—a household. A ritual area has been identified based on the recovery of faunal remains and the construction of a ditch at the site probably symbolized the idea of boundary or thresholds of the communities.

Based on the results of fauna analysis, issues concerning the subsistence of the Yangshao period in the Wei River valley will be addressed in detail in the following section. Furthermore, the site will be put in a broader context, trying to

explore subsistence strategy changes through time and how they related to increasing social complexity during the Neolithic in this region.

8.1 The interaction between people and pigs in ancient China

Archaeological findings suggest that pig domestication and husbandry may date back to 10,000 years ago (Albarella *et al.* 2007:3). In the Near East, the beginning of pig domestication has been proposed with faunal studies at a few sites, including Cayönü (Hongo and Meadow 1999; Ervynck *et al.* 2001) and Hallan Cemi (Rosenberg *et al.* 1998). The interaction between humans and *Sus* in China can be traced back to the Paleolithic when wild pigs were occasionally hunted. At most Paleolithic sites in China, remains of wild boar were recovered, but in small numbers. In the long history of human subsistence, deer hunting played a consistent role, with wild boar hunting being witnessed at a low level at throughout the Paleolithic and early Neolithic period. At least 10,000 years ago, during the Neolithic in northern China, when the use of pottery began, we see a sedentary life style, and some plant and animal domestication, such as millet and pigs. The pig was the only livestock animal involved in this initial domestication process in China and the success of pig domestication was an important event for Neolithic farmers; it represented one of the key attributes of settled agricultural life (the dog had probably already been domesticated in China by Paleolithic hunter-gatherers). Domesticated pigs became increasingly important in Neolithic subsistence systems later on, and remain so even today in most parts of China.

The pig is a controversial animal because certain people hate it while others love

the very same animal. Pig “haters” are well known, including Jews and Moslems, who mainly live in the Near East and North Africa today. Pig “lovers” including the Chinese, Japanese and inhabitants of New Guinea, are widely distributed in East Asia, Southeast Asia and the Pacific islands. Various hypotheses have been proposed to account for the wide occurrence of pork rejection in the Near East today and, although the religious reason has been most frequently discussed, interpretations based on ecological behaviour have also been made, in an attempt to understand the underlying reasons for pork avoidance in the Near East. The rejection of pigs in the Near East is related to human adaption to the local climatic conditions, and pig husbandry has been avoided by humans because of the ecological behaviour of the species（Harris 1985; Harris 1989: 42). The pig cannot adapt to the hot, dry climate and adult pigs will die if exposed to direct sunlight and air temperature over 98℉; certain level of humility and water resources are essential for the survival of the species. The Near East is notoriously hot and arid and in the Jordan valley, the air temperature can reach 110℉ during almost every summer and there is intense sunshine throughout the year. This kind of climate is adverse to the survival of pigs in this region. However, others believe that the history of this fascinating taboo is more complicated than that (Simoons 1994). The geographic distribution of archaeological sites with pigs present and absent from the 5th to the 3rd millennium BC around the Fertile Crescent was reviewed by Grigson (2007), suggesting that pigs only existed in areas moist enough to support dry farming, and the changes of the role that pigs have been played in the subsistence system were closely linked to environmental variations.

In contrast to the pig haters in the Near East, people in China have definitely been

pig lovers since ancient times. The close relationship between humans and pigs in ancient China can be illustrated by the fact that the Chinese ideograph meaning “home” consists of the signs for “roof” and for “pig”. Some attributes of wild boar make them ideal for early farmers to target for domestication. First, human beings were familiar with the behaviour of the species: there is a wide distribution of the species in China and their interaction with humans occurred throughout regional hunter-gatherer history. Second, the social tendencies of wild boar make them suitable for domestication: the social unit of the species is essentially the family; the females and their offspring live in large herds although adult males are usually solitary outside the breeding season (Zeuner 1963; Animal Diversity Web, University of Michigan Museum of Zoology 2011). Another characteristic of this species is that the pig is more profitable than any other large mammal, as it matures within a year and is capable of producing two litters in one year. The main motive of pig-breeding is undoubtedly that it is the most prolific and abundant supplier of meat and fat in ancient and modern China.

Unlike sheep and goats, pigs are hard to herd or drive. It is difficult to image how a nomadic community could cope with the art of pig-driving when they changed their habitat seasonally, and the presence of pigs argues against nomadism (Grigson 1995, 2007). Domesticated pigs are closely associated with permanent settlements, and it is unlikely that pigs were domesticated before the establishment of permanent settlements. So far, domesticated pigs have not been found at sites earlier than Neolithic agricultural ones, probably because the species is ideal for the sedentary farmers to manage. They can either be reared in confined spaces, or in a sty or even within the house, or be kept in a free range

way, finding food in the woods. Also, pigs are known for their omnivorous and sometimes indiscriminate diet, which makes it easy for humans to provide food for them. However, the successful husbandry of pigs requires water in greater amounts than that required by any other farmyard stock. This is likely a factor in settlement distribution patterns showing that Neolithic farmers chose to live in locales close to the rivers or streams with abundant water resources, which is essential not only to human beings, but also to their livestock, and presumably also for agriculture.

Over a long history, the pig is the principal meat supplier of meat to the Chinese, and there is no doubt that pig-breeding is of considerable antiquity in China. When pig-breeding initially started in China remains an interesting question. In many areas of China, pigs were also closely related to ritual activities. Pig mandibles were recovered from burials in different areas of China in the Neolithic period (Luo 2007). The sacrifice of pig was commonly practiced during the ceremonies in connection with oaths and treaties in ancient China. It has been suggested that the intensive pig production was important not only for human diet and ritual but also for the display of individual wealth and inequality in the rise of the political elites in China (Kim 1994). However, the political significance of pig husbandry is beyond the research themes of the thesis.

8.2 The animal subsistence strategies of the middle Neolithic in the Wei River valley

8.2.1 Pig domestication and husbandry strategies

Where did the earliest domesticated pig at Wayaogou come from?

Recent genetic studies suggested that China was an independent centre for pig domestication (Larson *et al.* 2005). However, since there is a wide geographic distribution of wild boar in China, it is possible that the pigs have been domesticated from local wild stock independently, in different regions of China (Zhang 1979; Luo 2007). As mentioned above, domesticated pigs are hard to herd and they are valuable to settled farmers only, and it is difficult to imagine that domesticated pigs were driven from one region to another, over a long distance. The behaviour of the species points to the hypothesis that probably the pig was domesticated independently in different regions of China.

The cultural complexes with evidence of early pig domestication in China have been reviewed in Chapter 1, including the site of Dadiwan, Cishan, Jiahu, Xinglongwa, and Xinglonggou. Since these sites appear so close in time but far apart in space, it is possible that there were multiple centres for pig domestication in northern China. The geographic distribution of these sites roughly coincides with that of communities where early millet farming occurred and it has been proposed that the millet farming revolution occurred independently at these geographically separate places (Bettinger *et al*. 2010). Of course, we cannot exclude the possibility that domesticated pigs were gradually exchanged from one village to another locale nearby, which probably occurred at the same time as the

demographic migration outward from centres of domestication and of cultural origin.

Morphometric data indicates that the length of pig M_3 at Wayaogou mostly falls into the range of 35-40 mm which is the overlap of wild and domestic pigs, with the range smaller than prehistoric wild boar. In addition, comparisons suggest the average length of M_3 from Wayaogou and other middle Neolithic sites is slightly larger than those from late Neolithic sites. The presence of large size individual bones suggests domesticated pigs and wild boar coexisted at the site. Wild boar was hunted probably occasionally, although pig husbandry was also practiced, and in fact seems dominant. Studies on pig remains at Wayaogou have provided a synchronic picture of the variations in human-pig relations at the site. From this synchronic picture, we can infer a number of hypotheses concerning pig domestication and husbandry strategies during the middle Neolithic. The occupation of Wayaogou probably does not represent the earliest stage of pig domestication and plant cultivation, since this probably occurred in the early Neolithic, if not earlier. In the case of Wayaogou, there are two other possibilities: the first is that domesticated animals and plants were introduced to the site by people at the same time as when they moved to this locale; second, human groups may have arrived at the site with ideas of plant and animal domestication and undertook these practices on local resources. The morphometric evidence at the site suggests that pigs most likely first appeared at the site with an already domestic status since most pigs seem significant smaller than their wild ancestors, although one or two were outstandingly larger. In the case of Wayaogou and other sites with similar deposits, it is possible that humans took domesticated pigs with

them when they moved from one site to another and occupied new areas.

Although evidence for domestic plant and other plant remains at the site is missing due to the poor retrieval methods and the lack of flotation techniques (quite common for archaeological excavations in the 1990s in China), recent findings and research from other sites in the Wei River valley (e.g. Dadiwan) suggest that millet was cultivated intensively at middle Neolithic sites. The large number of storage pits recovered from Dadiwan also supports the proposition that plant storage was practiced at the site, probably cultivated crops were stored to cope with the long and severe winters. From the studies of the faunal remains from the site, we get a clear picture of how meat resources were utilized, especially how domestic pig characterized the Neolithic subsistence system. In general, all the evidence from Wayaogou points towards an interpretation that community was one of farmers who were heavily dependent on millet, and also the animals relied on millet as provision of food. The group lived a sedentary lifestyle that entailed stable annual preparation of land, cultivation, harvesting and storage of plants, and an intergrated part of this was the provision of domestic animals supplemented by deer hunting. There are debates regarding whether sites of the Yangshao period were moved regularly as a result of a shifting agricultural system (Chang 1986: 114). A few sites dating to the Yangshao period were also recovered from Huangbao Town, such as Lijiacun, lvjiaya and Langzui (Banpo Museum 1984) which are all scattered in the Qi River valley, and are all very close to Wayaogou. The relationship between Wayaogou and these other sites could be very complex since they are close in space and some of them are contemporary. One hypothesis is that the distribution of these sites resulted from a

shifting agricultural system. However, this needs to be supported by other evidence from systemic studies of archaeological evidence, such as material culture and dating.

Domesticated pig: stalled or free range? Interbreeding with wild boar or not?

It has been suggested that the establishment of feral swine populations around some ancient settlements could have occurred, given the early use of free-ranging husbandry practices for the pig in some areas (Zeuner 1963; Clutton-Brock 1981). Ethnographic studies suggest that cross breeding between wild boar and domesticated pigs occurred in traditional pig husbandry practices (Redding and Rosenberg 1998). For example, in New Guinea, female pigs were reared and they roamed freely in, and around, the settlements and were allowed to mate with wild males. Based on the anthropological studies on swine populations in New Guinea, a female breeding model was defined by Redding and Rosenberg (1998): all managed pigs are the result of mating between wild boar and domesticated sows, and the managed population consists of females and their young. Genetic changes are the result of selection of females for breeding stock. Under this model, domesticated pig should have no size change as "any reduction in molar tooth size resulting from human selection of female breeding stock would be mitigated or lost by allowing the uncontrolled breeding of these females with wild males" (Redding and Rosenberg 1998: 68).

Although the interbreeding between domesticated pig and wild boar was clearly a common phenomenon in recent, and maybe past, societies, evidence from Wayaogou and other Neolithic communities in Neolithic China seems to fall into

a different model. Evidence from modern and ancient DNA suggests that although there is a wide distribution of wild boar in China, these populations have never been incorporated into domestic stock (Larson *et al*. 2010). Domestic pigs in China seem to have been isolated from their wild ancestors completely since the early stages of domestication. Recent anthropological studies in Corsica and Sardinia suggest that cross-breeding between domestic pig and wild boar is avoided, even though some herds of pigs were raised in completely free-range conditions, because they won't produce high quality off-spring (Albarella *et al.* 2007).

Morphometric studies suggest that the third molar (M_3) of pigs from the early Neolithic in China has a similar size range to those from the Paleolithic. The pig M_3 underwent a significant size change only from the middle Neolithic, even in the earliest phases. Thus, it would be more convincing if we account for the large size of pig M_3 present in the early Neolithic by the fact that morphological change is often a delayed event and difficult to detect in the earliest stages of domestication (Zeder 2006; 2010), rather than viewing breeding strategies as having changed between the early and the middle Neolithic.

Another problem concerning free-range pigs is that pigs may cause severe damage to crops and gardens by uprooting behaviour. This seems not to be a problem for non-agricultural societies, but it is a particularly serious problem for the communities practicing agriculture who highly rely on crop cultivation as a subsistence strategy. From this perspective, a proposition could be that pigs were either stalled or under human supervision in Neolithic China. Considering the

destructive behaviour of the species, if they were completely free range, especially with millet agriculture on which Neolithic farmers heavily relied, it is quite possible that pigs could have been allowed to roam freely around settlements. Of course, it is possible that pigs could have been turned loose and allowed to root during the daytime with human supervision. However, the time Neolithic farmers spent on raising pigs may be not have been completely separate from plant cultivation; it is not difficult to imagine that farmers working in the agricultural fields could, at the same time, keep their eyes on their pigs scavenging around the fields. This strategy continues to be practiced occasionally in some remote areas of China even today.

Feeding animals regularly is another way to control them and build up a reliable attachment between animals and human beings. In the evenings, when animals return home, they could have been fed on rations of garbage or human leftovers. Afterward, the animals could have been stalled in pens close to human dwelling areas. In this way, animals could remain under human control and maintain a close relationship with farmers. Stable isotope analysis of human and animal remains has been undertaken at four sites in the Wei River valley -- Dadiwan (Barton *et al.* 2008), Jiangzhai, Kangjia and Shijia (Pechenkina *et al.* 2005). The results indicate that the stable isotope profile of pigs and dogs imitate those of humans, and that both humans and domesticated animals, such as pigs and dogs, were using millet as their main food sources (Pechenkina *et al.* 2005). It seems that millet agriculture and pig husbandry depended on each other. That millet dominated diet of pigs probably indicates that their food supplies were mainly provided by humans rather than from scavenging around the settlements by themselves. This

supports the suggestion that pigs were domesticated at the site and relied highly on human for their food supply. However, whether pigs were fed on human leftovers or the husks of domesticated crops remains a question. The remains of animal pens were reported from the Jiangzhai site (phase I, 7,000-6,000 BP) in the Wei River valley (Banpo Museum *et al.* 1988). This evidence suggests pigs were probably stalled in this period. Although pig pens were not identified at Wayaogou, it is possible that some pits at the site were used as pens to stall pigs. The taphonomic analyses of pits at Wayaogou suggest that there are variations between these pits in terms of taphonomic process which may coincide with their different functions. The identification of dung remains at the bottoms of these pits could throw light on this question and enhance this argument in the future. Furthermore, with future scientific archaeological excavations, studies on the distribution patterns of pits with dung remains could help us to further understand pig husbandry strategies at the site and how they related to the social organization at the site.

Another pig-raising possibility to consider is one that has been ethnographically documented from New Guinea. Here, young pigs are treated as pets, and women take more responsibility in looking after baby pigs. Young pigs can be carried to the garden; when they get a little older, they are led on a leash attached to their forelegs; the leashes are not removed until the pigs learn to follow their mistress in a dog-like fashion (Rappaport 1975: 58). Although different communities may have different attitudes and behaviour towards their livestock, the studies in New Guinea still provide a possibility for understanding the complex relationships between human and pigs in Neolithic China.

Research on unusual pathological conditions is another potential way to investigate pig husbandry strategies, and the relationship between humans and pigs in the past. Pathologies associated with the teeth of pigs recovered from 2nd millennium BC deposits at Chagar Bazar, Northern Syria, have been used as evidence to suggest that pigs were being feed household scraps and kept in sties close to the houses (Albarella *et al.* 2006). Similar studies have been undertaken by Grigson (2007) and the presence of shed milk teeth in samples from the city street of the Sumerian city of Tell Abu Salabikh, southern Iraq (the 5th millennium BP), has been used to indicate that pigs were roaming in the street.

Pathologies on pig metapodia are worth noting because of their high frequency. There were 27 specimens of pig metapodia (III or IV) recovered from Wayaogou, out of which four have serious infections. The frequency of the occurrence of the infections is quite high (7.4%), compared with the “normal frequencies” of around 0.043%, as suggested by Siegel (1976). Metapodia with pathologies from Wayaogou are listed in Tab. 8.1. Two specimens with pathologies are observed and described in detail, with an attempt to investigate the causes: metacarpal IV specimen H199:191 and metatarsal IV specimen H162:40. In specimen H162: 40 there is a circumscribed area of new bone formation in the middle of the bone and roughly 30 mm in extent; for H199:191, the area of new bone is rougher and is probably more vascular and slightly smaller in extent, but seems to extend onto adjacent bone surfaces (Fig. 8.1). Probably these pathologies were caused by a bony reaction to an overlying soft tissue lesion, perhaps an infection of some kind.

Bone ID	Element	Pathology
H199: 191	metacarpal IV	fracture and infection
H162: 40	metatarsal IV	fracture and infection
H199: 146	metatarsal III/IV	Infection
H5: 15	metapodium III/IV	Infection

Tab. 8.1 List of metapodia with infections from Wayaogou

Fig. 8.1 Pig metacarpal IV (H199: 191) and metatarsal IV (H162: 40) with fractures and infections

A hypothesis concerning the high occurrence of pathologies on pig limbs could be that they were related to human husbandry strategies and activities. For example: a leash attached to the pig limbs could cause damage to the skin and underlying bone. This argument needs further support from other case studies and it would be more convincing with more samples with similar pathology recovered from Neolithic site in China. X-rays would also help give a more thorough understanding of these pathologies. Whatever the case, the pathologies on pig bones could provide important evidence for understanding the complexity of the relationship between humans and their livestock in the Neolithic.

Another aspect concerning the relationship between pigs and humans, is that pigs were probably quite precious for the community and people took good care of individuals in bad condition, and helped them recover rather than slaughter them. For example, when some individuals broke their legs, probably they were protected by humans and received special treatment from their master or mistress, so they recovered completely in their subsequent life.

Morphometric studies suggest that the size of pigs decreased gradually from the early Neolithic to the late Neolithic and the Bronze Age in China. Although body size change may not witness the initial steps of animal domestication (Zeder 2006), it can be used to document processes of domestic animal breeding. The domesticated pigs in the Neolithic were relatively smaller than their wild ancestors, and larger than those in the Bronze Age. Few studies on faunal remains from Iron Age China have been undertaken and the situation for this period is currently unclear. Generally speaking, the body size of pigs is highly dependent on feeding conditions (Boessneck 1958). Size fluctuations of pigs in European

populations have been observed. Studies suggest that the decrease in size continued through the Neolithic and Bronze Age in central Europe, until the beginning of the Roman period. A distinctly larger size can then be observed within the area of Roman occupation, which Boessneck (1958) attributed to improved living conditions. From this perspective, the size variations of pigs in the Neolithic and the Bronze Age of the Wei River valley may relate to different feeding strategies and living conditions in the different periods.

8.2.2 The balance between pig herding and deer hunting

Faunal evidence at Wayaogou suggested that intensive pig husbandry was practiced at Wayaogou, and probably provided reliable protein and meat sources for human groups. However, deer hunting was clearly still an important activity, with deer remains making up more than 50% of all the remains from the site (NISP). Faunal remains belonging to the contemporary phase (Banpo phase) at the Dadiwan site show a similar pattern, with an even higher percentage of deer remains (chapter 4, Fig 4.4). Various lines of evidence suggest that pigs were intensively managed at sites in the middle Neolithic period. Compared to livestock herding and cereal cultivation, hunting is high risk endeavor since it may produce a far lower return in terms of calories than that obtained through gathering or cultivation, despite many hours of pursuit (Kent 1989). Also, hunters sometimes need to travel long distances to chase their prey. Ecological studies described in Chapter 4 indicate that deer hunting at Wayaogou mainly took place in woodland and forest far from the site. Thus, hunting may not be a preferred strategy of human groups in terms of stability of meat or protein acquirement, and it is not an ideal choice as a subsistence endeavor for a settled society. Why deer hunting persisted in the Neolithic and remained important for communities is an

interesting question to explore. Considering the complexity of human behaviour, various motivations may be involved in hunting activities at the site. In this section, different hypotheses will be proposed for interpreting the interaction between humans and sika deer at Wayaogou, not only from a subsistence perspective, but also from the social meaning perspective.

Deer hunting activities can be traced back to the Paleolithic and played an important role in the subsistence system of hunter-gatherer communities. However, the interaction of deer taxa and human beings in China's long history remains cloudy. This is mostly due to poor excavation techniques and research methods. From the historic perspective, it is widely acknowledged that early millet farming in north China evolved from intensive hunter-gatherer adaptations represented by the late Pleistocene micro-blade tradition of northern China (Bettinger *et al.* 2010). The presence of microblades and other microliths at Wayaogou suggests that the community was probably linked to hunter-gatherer communities in northern China, of which deer hunting was a traditional subsistence activity. Thus, it appeared that deer hunting was a traditional activity for these communities and their ancestors.

Furthermore, from a social perspective, there are many possible motivations for the continuity of hunting traditions in the Neolithic communities. For example, hunting may have been an important medium to confer importance and status on males in societies where cultivation and herding occupied a large portion of time and energy. In a recent ethnographic account of hunting societies, hunting techniques are critical for males to determine their social status, and most commonly, the best hunters would take on leadership of the community. This

tradition continues on into some modern sedentary horticultural societies, for example, in Cahinahua, hunting is a way of showing male identity and men define themselves as indispensable hunters, and can attempt to control women through controlling their mating (Kensinger 1989).

The motivation for deer hunting in the Neolithic communities may also have involved ritual activities. Ritual traditions may have continued on from previous hunter-gatherer practice into Neolithic societies. Despite the important role of pig herding, hunting, especially of sika deer, was probably ritually important. Ethnographic studies from New Guinea suggest that hunting of feral pigs played an important role in major ritual ceremony, no matter that in the highland the political economy was based on intensive pig husbandry and plant cultivation, and in the lowland hunting was still important in the subsistence system (Rappaport 1975). From Wayaogou, the seasonality studies suggest that most deer were hunted during the winter, when males were carrying antlers. Deer antlers may carry social or ritual meaning for the society and the pursuit of antler may have been an important reason for hunting deer. In addition, taphonomic process studies on sika deer bones suggest that body part representation of sika deer is heavily influenced by the bone tool production at the site (see details in chapter 6). The reason why sika deer bones were more frequently used to produce tools is that their structure, weight and strength make them more appropriate for bone tool, whereas pig bones were not preferred for making bone tools as they are always quite oily. Thus, obtaining raw materials, such as bones, and other secondary products, such as skin and leather, could be another important motive for hunting. Deer skin is an ideal raw material for clothing, but unfortunately, fabric remains

did not survive at the site.

Another reason why hunting was still practiced intensively at the site is that humans may have still relied on deer as a source of meat and protein at this stage. The ecological behaviour of pig means that they can be maintained at certain numbers, but this may not have been sufficient to provide protein for the whole community. An impressive characteristic of the pig is its rapid reproductive rate which probably make swine husbandry attractive to humans in the first place. However, keeping large herds of pigs can be a disaster because pigs are quite destructive in their search for food, especially in relation to millet agriculture. Pigs may be quite troublesome to crops since there is a much greater possibility of pigs invading agricultural fields if they existed in large number. In New Guinea, people try to keep pig herd size at certain levels to avoid this problem (Rappaport 1975).

Millet agriculture is on a seasonal cycle in this region today; the cultivation of the crops commences in spring, and harvest mostly occurs in autumn. The slaughtering of pigs before early spring could be a conservation strategy for millet agriculture since pig herding is quite competitive with millet cultivation. In this perspective, pig herding and cereal cultivation could have relied on each other, for example, plant waste from agriculture provides fodder for pigs, and pig dung may be used as a fertilizer for agricultural fields, as it is today.

The intensification of pig husbandry was highly reliant on the intensification of millet cultivation, with plant waste from agriculture providing fodder for pigs. As mentioned above, feeding pigs with millet products or human leftovers is an

important strategy. Linear enamel hypoplasia analysis suggests that there was a relative high frequency for the occurrence of LEH in the pig population at Wayaogou and other Neolithic sites in the Wei River valley. This indicates that pigs experienced certain feeding stress under human control. Of course, various factors may account for the physical stress of animals, but fodder shortage may have been an important one. From this perspective, the scope of pig herding at Wayaogou may have been closely related to the food abundance and the intensification of millet cultivation. Probably, during the early phase of the middle Neolithic, millet cultivation was only beginning to be intensive, and therefore could have only provided limited surplus to feed livestock.

The seasonality study suggests that most pigs were killed during the winter, which is a lean season, in terms of plant resources. The early spring has been characterized by a special term “Qing huang bu jie” (a gap between the green and yellow) in ancient China and even today in poorest areas. It means that the harvests (yellow) from the previous year has run out and the fresh resources of the following year (green) are still not available. The seasonality studies suggested that large number of pigs were killed in winter or early spring, which is a “Qing huang bu jie” season. This indicates that humans were still facing subsistence pressure at this stage, although the intensification of food production had begun.

Pigs can be used as “vacuum cleaners” and they can provide a sanitation service for the settlement. They can eat garbage and human faeces. Not only do they thus assist in keeping residential areas clean but they also convert waste into materials that may be utilized by their masters. Ethnographic studies in New Guinea

suggested that a small number of pigs are sufficient to keep residential areas clean and also sufficient to suppress weeds and superfluous seedlings in abandoned gardens. As mentioned above, a large herd, on the other hand, may be troublesome—the greater the number of pigs, the greater the possibility of their invading producing gardens, with concomitant damage to crops and young secondary growth (Rappaport 1975).

8.3. Animal subsistence in the broader context: changes in the subsistence strategies through the Neolithic and their relationship to social complexity in the Wei River valley

The Wei River, also known as Guanzhong plain, is a fertile alluvial plain formed by the Wei River and its tributaries. From the historical perspective, the Wei River valley has been a cultural and political centre from ancient times. Paleolithic sites have been discovered in this region, along with human remains, such as *Homo erectus lantianensis* in the early Paleolithic, Dali man in the middle Paleolithic, and the late Paleolithic site of Hetao. The early Neolithic communities started to inhabit this region from around 10,000 years ago and this is one of a few centres for the emergence of agriculture in China. During the middle Neolithic, 5,000 years ago, the Yangshao communities were flourishing in this region representing the highest developed regional society at that time. In the historical period, from the Western Zhou Dynasty, eleventh century BC, at least ten dynasties have established their capitals in this region (Zhu 1986).

For the Neolithic, the Dadiwan occupation is known as the earliest agricultural community in this region, with the practice of a sedentary life style and plant and

animal domestication. During the middle Neolithic, the Yangshao communities were believed to be highly developed in this region, with the intensifying of plant cultivation and animal husbandry methods, and this represents the first flourishing agricultural society in northern China. However, interestingly, during the late Neolithic, the Wei River valley experienced a social decline and this continued until the early Bronze Age when the first states in China formed in the Central Plain (Henan Province) (Liu and Chen 2003). In Fig. 8.2, I chart the timelines of the appearance of major components of Childe's Neolithic 'bauplan' and social development in the Wei River valley. Then, I will put the animal subsistence research from Wayaogou into a broader context, to explore how the agricultural society emerged, developed and declined in this region. The dynamic relationship between climate fluctuations, subsistence changes and social complexity will be assessed in detail to explore issues such as the diversity of human reactions and responses to environmental change during the Neolithic in this region.

8.3.1 The emergence of agricultural communities in Wei River valley

It has been proposed that the earliest agricultural communities emerged in northern China at least 10,000 years ago (Smith 1995: 136; Lu *et al.* 2009). The Yellow River, along with the Yangtze River, both originating in the Tibetan Plateau, flow to the east and drain the vast woodlands of eastern China. The Yellow River and its tributaries witnessed the earliest millet agricultural development, whereas the Yangtze River was the motherland of the earliest rice farming.

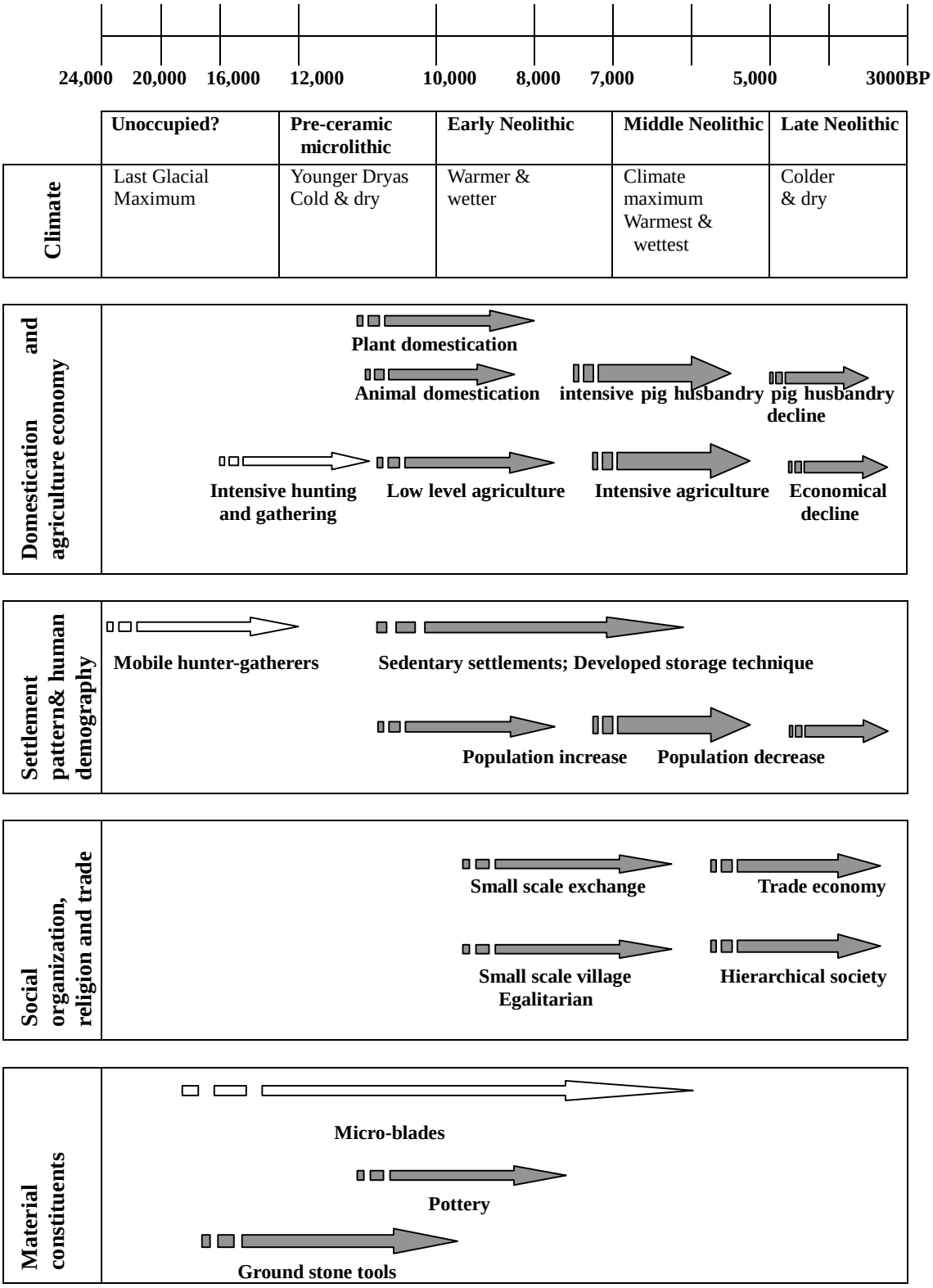


Fig. 8.2 Timelines of the appearance of major components of Childe's Neolithic 'bauplan' and the social development in the Wei River valley (using information from Bettinger *et al.* 2010; Lu 1999, 2006; Kuzmin 2006; Crawford 2009; Lu *et al.* 2009, Liu and Chen 2003; Liu 2004; Chang 1986)

The common millet (*Panicum miliaceum)* and the foxtail millet (*Setaria italica)* were the two most common species cultivated during the Neolithic time in northern China. A few sites have witnessed the beginning of millet cultivation in northern China, including Cishan in Hebei Province, Peiligang in Henan Province, Houli in Shandong Province and Dadiwan in Gansu Province (Fig. 8.3). Recent archaeobotanical studies suggest that the earliest significant common millet cultivation system was established in the semiarid regions of China by 10,000 cal BP (Lu *et al.* 2009). Evidence from the Cishan site pushes the timing of agriculture origins in North China back to the Pleistocene—Holocene boundary (Crawford 2009). So far, the archaeological findings and data have not been adequate to solve the issues of when and where the earliest plant domestication was established in China. Recently, Bettinger *et al*. (2010) proposed that it is possible there were multi-centres for the millet farming revolution of northern China, since these centres with early domesticated millet appear close in time but far apart in space. In general, the agricultural revolution in northern China is not well understood and the model remains quite confusing to archaeologists because this tradition can not be traced *in situ* out of a long hunting and gathering tradition. Other issues associated with the attributes of the Neolithic Revolution in China, such as the beginnings of sedentary life, the first steps of plant cultivation and animal domestication, have attracted many efforts from scholars in China and also outside the country. However, these questions remain cloudy, mostly due to the poor recovery techniques and research methods in China.

Following the archaeological survey by the State Administration of Culture Heritage, the regional settlement pattern in the Wei River valley has been

reviewed by Liu (2004). The early Neolithic sites were seen to be sparsely scattered in the Wei River valley and about 20 sites, dating to the early Neolithic (8,500-7,000 BP), have been found in this region. These sites are all small in size, except three – Baijiacun and Laoguantai and Dadiwan – each measuring more than 10 ha in area. Recent archaeological work at the Dadiwan site provides clues for the transition from intensive hunter-gatherers to early agriculturalists in this region, and it has been proposed that "millet agriculture did not emerge from a local hunter-gatherer base, but was rather introduced by groups migrating into areas that were either unhabited or only sparsely occupied" (Bettinger *et al*. 2007: 97), since archaeological data at present do not provide any stratigraphic sequence or statistically convincing connection between forager and millet agriculture in northern China (Bettinger *et al.* 2007; Bettinger *et al.* 2010). The earliest evidence for agriculture in the Wei River valley can be traced from the deposits of the early Neolithic from Dadiwan, and from this evidence, it has been proposed that the broomcorn millet (*Panicum miliaceum)* was the first crop to be cultivated in the early Neolithic in the Wei River valley (Barton *et al.* 2009).

The climate fluctuations and environmental changes throughout the Holocene have been reviewed in detail in Chapter 3. The Dadiwan community, the first known agriculture complex in northwest China, coincided with a period when the climate was warmer and more humid since the Last Glaciation (Bettinger *et al.* 2007). These conditions were favourable to plant domestication in this region. However, the climate of this period was still relatively dry compared to the middle Neolithic, when northern China experienced its climate optimum. It has been suggested that the relatively dry conditions in the early Holocene may have been

favourable for the common millet (*Panicum miliaceum),* more than the foxtail millet (*Setaria italica)* (Lu 2009). Analysis of plant remains analysis suggests that only broomcorn millet was domesticated in the early Neolithic in the Wei River valley and it was cultivated extensively in the central Wei River basin shortly after *ca.* 8,000 *cal.* B.P. (Crawford 2009).

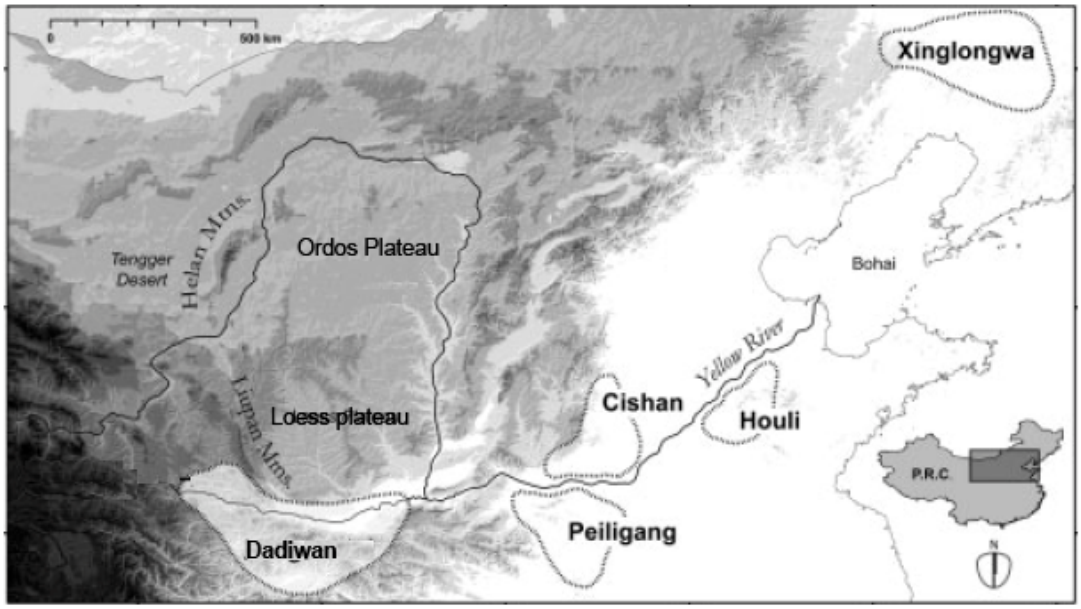


Fig. 8.3 Early communities with millet agriculture in northern China (adapted from Bettinger *et al.* 2007)

Pig domestication seems closely related to plant cultivation in China, since crops not only provide food for humans, but also provide fodder for livestock. The sites and locations with early pig domestication evidence is consistent with those with the earliest records of millet cultivation in northern China, such as Cishan site in Hebei Province, Xinglonggou and Xinglongwa in Inner Mongolia, and Dadiwan in the Wei River valley (Bettinger *et al.* 2010) (Fig. 8.3).

The earliest evidence for pig domestication in the Wei River can be traced from

archaeological remains at Dadiwan. From analyzing the faunal remains, recovered from the excavation in the late 1970 to the early 1980s, the domesticated status of pigs at the site has been proposed based on two lines of evidence: first, the average length of M_3 is 37.06 mm; second, most pigs were killed between one and two years old (Qi *et al.* 2006). However, as mentioned in Chapter 1, there is a serious problem with the studies on the faunal remains since the whole assemblage at the site was treated as one unit, although the site lasts from the early Neolithic to the late Neolithic. Recent studies on plant remains suggested cultivation of broomcorn millet started in the Dadiwan phase I (7,200 cal BP) and domesticated foxtail millet was found in the Yangshao period (5,000-3,000 cal BP) (Bettinger *et al.* 2007). Isotope analysis of pig, dog and human bones at the Dadiwan site suggests that humans and dogs were provisioned with broomcorn millet in the Dadiwan phase I (7,200 cal BP), and pigs were not fed on millet until the Dadiwan phase II (Yangshao period, 5,000-3,000 cal BP) (Barton *et al.* 2009). Thus, based on stable isotope analysis, Barton *et al.* (2009) proposed that pig domestication occurred between 7,200 and 5,800 cal BP in this region. However, we should bear in mind the fact that pigs have a broad dietary spectrum and isotope evidence may not document the first steps of pig domestication since it is not necessarily the case that pigs were fed with millet in the early stages of domestication.

The evidence for the beginning of pig domestication in this region is not solid, and whether pigs were domesticated in the early Neolithic needs further evidence to become a firm case. However, the fact that pigs underwent significant size changes in the early phase of middle Neolithic suggests that the practice of pig herding had probably already started in the early Neolithic. The relative

proportions of different taxa at Dadiwan and other early Neolithic deposits from other sites, such as Baijiacun and Guantaoyuan (Fig. 8.4), suggest that pigs make up less than 30% of the faunal remains. This indicates that, regardless of whether pigs in this period were domesticated or wild, they contributed a relatively small part to the subsistence, and that animal subsistence of this period was still dominated by wild species hunting. The proportion of plant cultivation in human subsistence is not clear since systematic quantified studies on plant remains have not yet been undertaken. However, based on studies on the usage of grinding stones, some scholars have proposed that cereal farming did not contribute much to the subsistence economy in the early Neolithic (Liu *et al.* 2010). This stage is characterized by low level food production, with human subsistence based on a mix of wild and managed resources.

8.3.2 The intensification of plant and animal domestication and social complexity process in the Wei River valley

The middle Neolithic (the Yangshao period), which is widely acknowledged as representing the first flourishing agricultural society in northern China, witnessed the intensification of plant cultivation and animal husbandry. In the Wei River valley, domestic pigs were widely used and contributed a larger proportion to the subsistence compared to the early Neolithic. Foxtail millet was also domesticated in this period and started to make contributions to human and animal diets. Studies from the site of Jiangzhai, Shijia and Kangjia (Fig. 8.4) suggested that stable isotope profile of pigs and dogs imitated those of humans, indicating that both humans and domesticated animals, such as pigs and dogs, were using millet as their main food (Pechenkina *et al.* 2005). A symbolic human-plant-animal linkage in the middle Neolithic can be perceived: people cultivated, harvested and

stored enough broomcorn millet and foxtail millet as provisions for themselves and their hunting dogs and livestock. Pig husbandry became a more reliable resource to provide protein and fat.

Paleoenvironmental studies suggest that the Yangshao communities experienced a period of Climate Optimum, and it was the warmest and the most humid period in the Holocene. Analysis of taxa representation and frequency at Wayaogou indicates a wide range of species present at the site, representing a variety of ecological zones used. Most species can only be found in the most remote areas of this region today. Some species, such as water deer and bamboo rat, are absent in the Yellow River valley and can only be found in southern China today. The evidence from faunal remains seems consistent with the proposition that the Yangshao occupation was within the Climatic Optimum and it was warmer and more humid than present. During the Yangshao period (7,000-5,000 BP), the Wei River valley became densely populated and over 1,200 sites dating to this period have been recovered. This period has been divided into three phases: the early, middle and late Yangshao period. Since the published data did not provide valid chronological information for all the middle Neolithic sites, it is difficult to investigate the settlement pattern change within this period. However, it seems that the number of archaeological sites dating to the early phase of the middle Neolithic increased and the average size of these sites also increased. The middle phase of the middle Neolithic witnessed the cultural flourishing and the population increased in this region as large quantities of new sites emerged; certain sites were prominent because of their large size and rich archaeological findings. Recent archaeological work at the Yangguanzhai site, shows that a very

large (80 ha) moat-surrounded settlement developed in this region, which probably served as the regional centre, and some scholars even propose that it represented the earliest city in China (Yang 2010). During the late phase of the middle Neolithic, the society also seems complex, and is represented by another regional centre, the Anban site (80 ha). A large public building at the centre of site has been proposed as place for hosting ritual activities, since special deposits have been recovered, including a large pottery scoop, large quantities of animal bones including several pig mandibles painted with red pigment, and some small clay figurines.

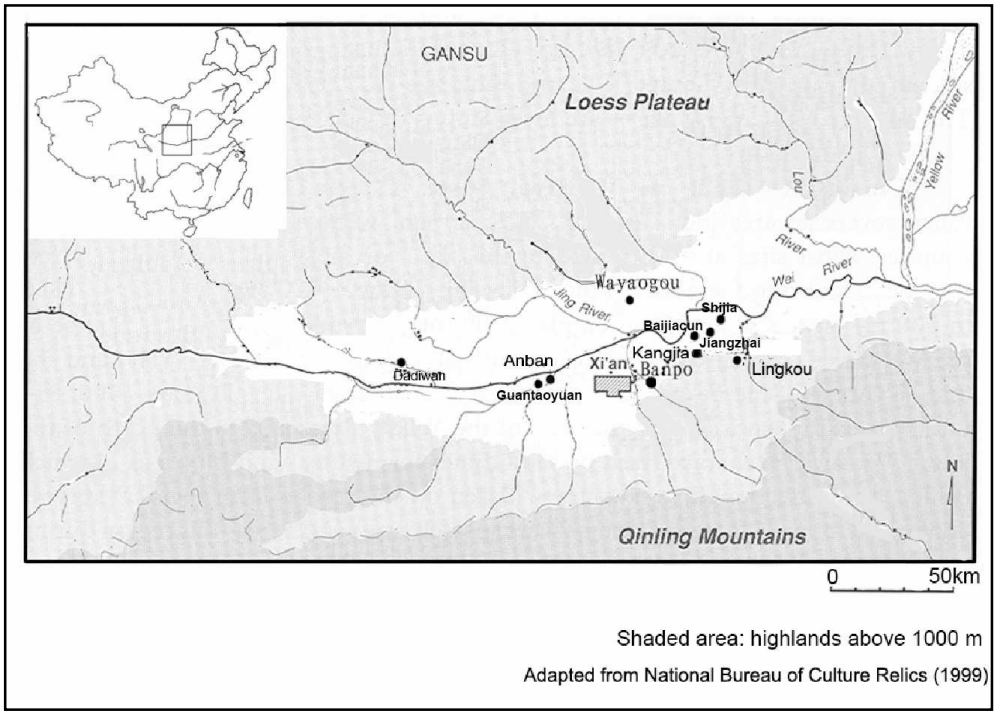


Fig. 8.4 The distribution of archaeological sites mentioned in this section

The relative proportions of faunal remains from Wayaogou suggests that by the early phase of the middle Neolithic (the Banpo phase), domestic pig played an important role in the subsistence system since pig remains make up 38% of all the

faunal remains (NISP) at the site, which is much more significant than the proportions of the early Neolithic sites (mostly around 20%). This implies that intensification of pig husbandry was practiced at the stage. However, since the proportion of deer still outnumbered that of pig, this implies that the early phase of the middle Neolithic, the Banpo phase, was perhaps characterized by low level food production with increasing reliance of managed resources. Remarkable changes in terms of subsistence occurred after this stage. During the late phase of the middle Neolithic, which can be represented by the Quanhucun site, pig husbandry intensified, and pig remains make up around 80% of all the faunal remains. Subsistence during this stage relied highly on an agricultural economy.

The intensification of millet cultivation and pig husbandry was consistent with the expanding number and sizes of sites. The interaction of subsistence change and social complexity can be investigated through settlement pattern change and changes in plants and animal remains. It would be reasonable to argue that the intensification of pig husbandry had relied on the development of foxtail millet agriculture in northern China since this highly productive plant not only provides enough stable food for humans, but is also a supplement food for pigs. The relationship between plant cultivation and pig domestication in the Neolithic of China remains an interesting question to explore. Ethnographic studies from New Guinea demonstrate that intensity of crop production leads to an even greater increase in the pig populations compared to the human population (Rappaport 1975).

8.3.3 The decline of society and change of subsistence in the Late Neolithic in the Wei River valley

The late Neolithic witnessed a decline in the number and size of settlements in the Wei River valley (Fig. 8.5), and about 700 sites dating to the late Neolithic have been found, of which about 58% continue from the previous period (Liu 2004). In contrast to the Central Plain (Henan) and Eastern China (Shandong Province), where the number of sites from the late Neolithic period (the Longshan period) increased dramatically, the decline in the number of sites in the Wei River valley is worth noticing. Furthermore, no site of this period has been recovered with relics of city walls or other defensive features. Rich burials with elite prestige good (such as jade ritual items and elaborate ceramic objects) were also absent in the region, unlike other regions in northern China.

Paleoenvironmental studies on pollen, sediment profiles, and isotopes suggest that it became drier and colder in the late Neolithic in northern China and probably the vegetation changed significantly (An *et al.* 2004; An *et al.* 2006; Feng *et al.* 2006). Changes in the vegetation, landscape and soil associations provide different environmental opportunities for agriculturalists who settled in this region, and they may have changed their economic strategies accordingly. It seems that the sites of the Wei River valley were undergoing a period of economic distress, probably due to the increasing desiccation in the late Neolithic. This resulted in the sudden abandonment of many sites. As mentioned above, pigs have limited environmental tolerance and with this adverse climate conditions, declines of pig population would be expected, and indeed this is the case for sites of the Wei River valley. Faunal report from Kangjia site (Liu *et al.* 2001) suggests that pigs

contributed less to subsistence in the late Neolithic compared to the middle Neolithic in the Wei River valley and, in contrast, deer hunting played an important role (Fig. 8.6). At the meantime, some new species were added to the livestock spectrum during this period in northern China, including cattle and sheep/goat (Yuan *et al.* 2007; Flad *et al.* 2007). However, they were occasionally recovered from the late Neolithic sites, but only in small numbers from sites of the Wei River valley. The pattern that declined representation of pigs in the faunal assemblages coincided with increasing desiccation has been also observed with studies from some archaeological sites in the Near East (Grigson 2007).

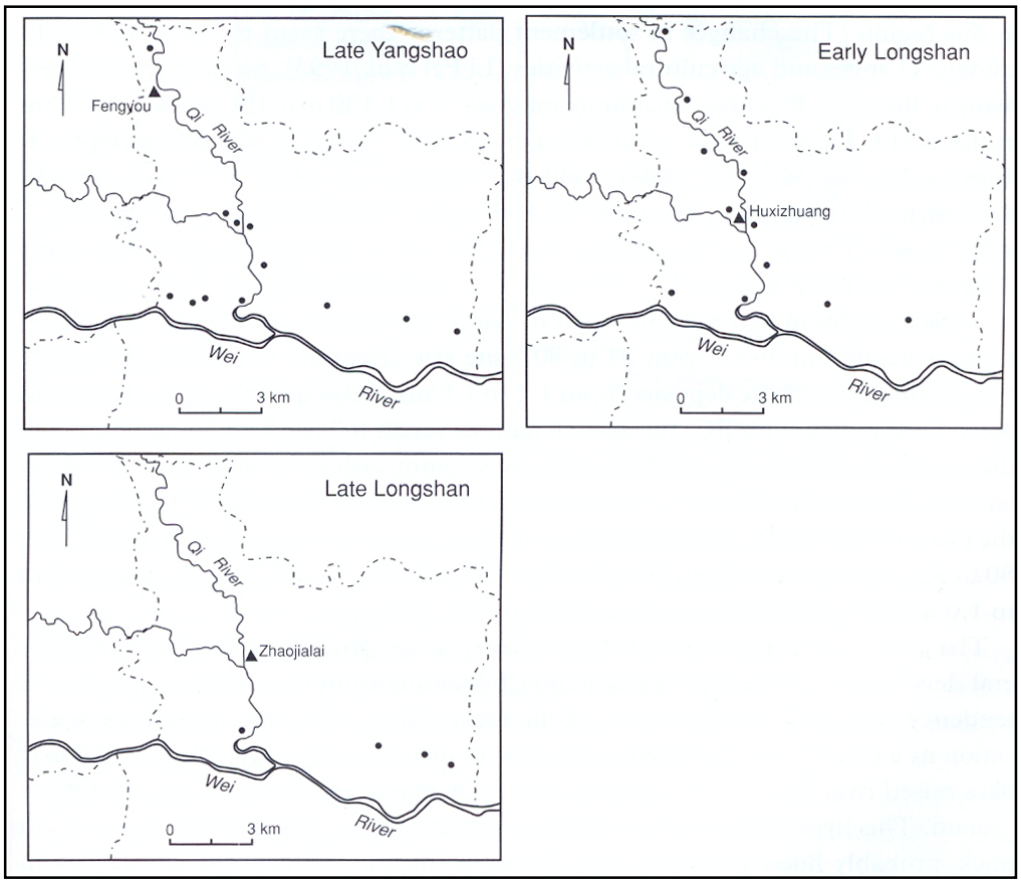


Fig. 8.5 Site distribution in the lower Qi River (tributary of the Wei River) valley, showing a decline of site density from the middle Neolithic to the late Neolithic (Adapted from Liu 2004) (● indicate archaeological sites; ▲ indicate modern towns)

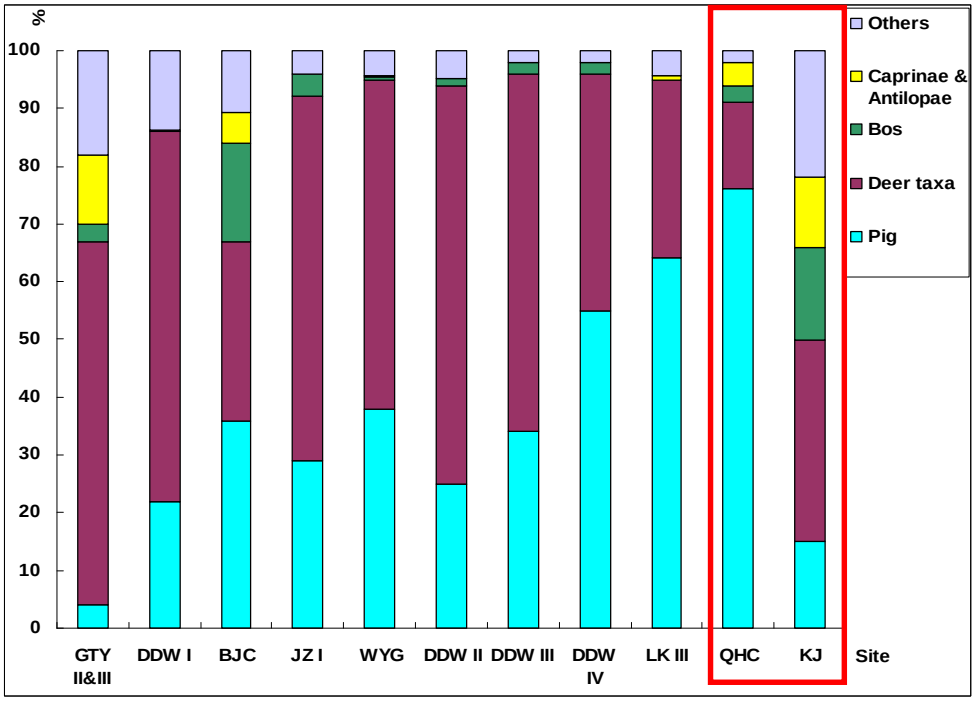


Fig. 8.6 Percentages of the main taxa from Neolithic faunal assemblages in the Wei River valley; the red rectangular area shows the decline in representation of the pig and the increased representation of deer from the middle Neolithic to the late Neolithic.

It has been proposed that the relationship between ancient societies and their environments are neither simple nor direct (Rosen 2007). Different societies may have different responses to cope with climate change. In the late Neolithic, the Wei River valley experienced a social decline with adverse environmental conditions. Ironically, at the same time, in the Central Plain (Henan Province) and Eastern China (Shandong Province), the Longshan communities were flourishing and finally, the first Chinese state emerged in the Central Plain. The emergence of the first states involved changes in many aspects of society. The most impressive one is the development of a trade-based economy which probably played an important role in this process (Rosen 2007). The trade relations were important for forming an exchange and power base for the emerging elite controllers of these

early societies in China (Liu and Chen 2003; Liu 2004), and fro long distance exchange of precious goods, such as some cowries with origins in the Indian Ocean region (Peng and Zhu 1999), which appeared in the late Neolithic and developed further in the early Bronze Age in the Central Plain.

Humans are not just responsive to natural environmental changes but play an active role in the creation of their own environments. Human activities have transformed the landscape of many parts of the world. As mentioned above, the Wei River valley was densely inhabited in the middle Neolithic and intensive pig husbandry and millet cultivation was practiced at the middle Neolithic sites. The intensification of agriculture may have had a great impact on the landscape and vegetation around sites, and it is possible that after 2000 years of exploitation, the fertility of soil in the Wei River valley became less suitable for millet cultivation. With these circumstances, different subsistence strategies were required for humans to survive. The decline of the status of pig husbandry and the increase of the importance of deer hunting suggests the ecological adaption of human beings.

This process probably also coincided with population migrations during the late Neolithic. It is possible that humans were moving out of Guanzhong Plateau (the Wei River valley) into surrounding areas gradually during the late part of the fifth millennium BP, since the process of population decrease and cultural decline in this region, seemed parallel with population increase in surrounding regions (Liu 2004), such as the Central Plain (Henan Province) and northern Shaanxi.

In the Central Plain, the development of complex societies has been reconstructed

by Liu (2004) based on the studies of regional settlement patterns. The appearance and development of settlement hierarchy and administrative hierarchy points to the development of complex societies in the Central Plain. With increasing social complexity, a trade-based economy was developing, which may have attracted populations from the Wei River valley. This can be seen by the drastic increase in population in the Central Plain during the late Neolithic. This process probably contributed to the social complexity in the Central Plain and finally, the first state emerging in this region (Liu and Chen 2003).

Another trend towards increasing site numbers in northern Shaanxi in the late Neolithic period is worth noticing, since it is also coincided with the decline of site numbers in central Shaanxi (Guanzhong plateau). For a long time, the landscape of northern Shaanxi was dominated by steppe grass (Winkler and Wang 1993) and the subsistence strategies in this region were quite different from the Wei River valley. Faunal remains of the late Yangshao Period from the Wuzhuang Guoliang site in Jinbian County, Shaanxi Province, show pigs and hare dominating the fauna remains, with pig remains at 31% of and hare at 49% (Hu and Sun 2005, Fig. 8.7). During the late Neolithic period, domesticated sheep and goat arrived in northern China probably from the West (Yuan and Flad 2007). Although how and when exactly these species were transmitted is not quite clear so far, their arrivals greatly influenced the subsistence strategies of this region. The caprine species represent a totally new life style, the pastoral life style, and this new subsistence strategy was quite suitable for the northern Shaanxi since the landscape was dominated by steppe grass. This can be seen in the faunal remains recovered from sites in northern Shaanxi. Faunal remains were reported from the

Huoshiliang site in Yulin County, Northern Shaanxi Province (Hu *et al.* 2008). The site dates back from the late Neolithic to the early Bronze Age and the species spectrum suggests that caprines, especially goats, dominated the assemblage (60%). Sheep were also present, but in relatively smaller numbers (Hu *et al.* 2008). Various lines of evidence point to a domesticated status of these caprine species at the site (Hu *et al.* 2008, Fig. 8.7). With this new life style, the northern Shaanxi could be an alternative ideal dwelling place for late Neolithic groups, and it is quite possible that, with the adverse climate condition and deterioration in the late Neolithic, people were also moving out the Wei River valley to the Northern Shaanxi where the pastoral life was much more suitable. The increase in site numbers, and presumably population, in the late Neolithic in northern Shaanxi supports this hypothesis. However, the processes and routes of population movement are not clear at present and this hypothesis needs to be tested with new archaeological findings in the future.

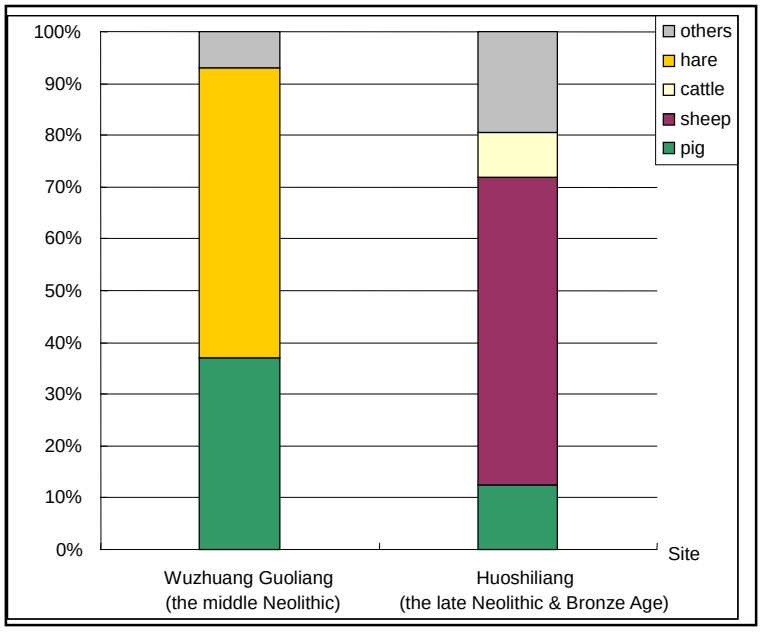


Fig. 8.7 Diachronic changes in relative proportions of main taxa from sites of northern Shaanxi; data adapted from Hu and Sun (2005) and Hu *et al.* (2008)

8.4 Conclusion and future research directions

This project has mainly focused on the subsistence studies of the middle Neolithic in the Wei River valley, attempting to understand the dynamic relationships between humans and animal species, especially the pig and sika deer. Various zooarchaeological methods have been adopted in this study, including species representation, morphological study, and ageing and cull pattern studies based on tooth eruption and wear stages, and epiphyseal fusion. Meanwhile, published data from other Neolithic sites in this region were drawn together for comparison, attempting to get a more complete of the Neolithic subsistence. Spatial analysis has also been used to understand the distribution patterns of faunal remains at Wayaogou and other utilization of animal bones beyond the subsistence economy.

Data analysis and interpretation of evidence was mainly undertaken in chapters 4, 5, 6 and 7. In this chapter (8), some important issues concerning animal domestication and animal subsistence of the Yangshao period in the Wei River valley are discussed in detail, from which some conclusions will be drawn.

8.4.1 Pig domestication and husbandry strategies

Based on zooarchaeological research at Wayaogou and comparative studies from other sites, a few hypotheses concerning the processes of pig domestication and various aspects of pig husbandry strategies can be proposed, providing a clear scenario of the interactions of Neolithic farmers and pigs.

1) Morphological studies of pig remains from Wayaogou suggest most pigs were domestic at Wayaogou; Wayaogou did not witness the beginning of pig

domestication and probably pigs with a domestic status were brought to the site by humans; wild boar were occasionally hunted by humans, but in small numbers.

2) Evidence from mandible wear stages and linear enamel hypoplasia suggests that probably single farrowing of pigs was the most common case occurring at the site, and double farrowing was a rare phenomenon or absent; most pigs were born in spring and slaughtered during the lean seasons, probably in winter and early spring.

3) Pigs were primarily exploited for meat and pig bones were seldom used for bone tool manufacture.

4) From the ecological and behavioural perspective, the proposition that pigs were isolated from their wild ancestors completely in the early stage of domestication in Neolithic China is a fairly solid case since the species were quite destructive to millet agriculture if they were free ranged. Probably pigs were closely supervised by humans, and interbreeding between domesticated pigs and wild boar was avoided because it would not produce high quality offspring. I argued that pigs were probably stalled at night and turned loose and allowed to roam freely around the settlement with human supervision during the daytime.

8.4.2 Deer hunting practices

Based on sika deer bone studies at Wayaogou, the following conclusions can be

drawn:

1) Selective hunting strategies were practiced at Wayougou and most animals did not prey until they reached their maximum body weight. The reproduction of the species seems to have been considered by humans since most of them were hunted after their optimum mating ages.

2) Seasonality studies suggest that most sika deer were hunted during the winter when the species tends to congregate.

3) Sika deer were not only exploited for their meat, but also for their bones which were intensively used to make bone tools.

8.4.3 The subsistence strategies of the middle Neolithic

Faunal studies at Wayaogou and comparative studies from other sites provide clues to trace subsistence strategies during the Neolithic:

1) The range and the relative taxonomic abundance of animals at Wayaogou suggest that pig and sika deer played an important role in the subsistence system.

2) The intensification of pig husbandry took place in the middle Neolithic; animal domestication and millet cultivation relied heavily on each other, and human probably needed to consider for maintaining strategies balance.

3) Various motives concerning social factors, such as traditions and male social roles, and subsistence strategies relating to the behaviours of pigs and sika deer, spurred humans to continue sika deer hunting, which continued to play an important role at Wayaogou and other sites of the same period.

8.4.4 Subsistence change through time

An animal subsistence studies have been put in a broader context, to investigate how the subsistence changes related to social evolution in this region.

Generally speaking, pig domestication and deer hunting were the main subsistence strategies during the Neolithic in the Wei River valley. Pig domestication was closely related to millet cultivation and sedentary life style in China in the early Neolithic. These events occurred in parallel with the climate improvement since the Last Glacial. During the middle Neolithic, with the Climate Optimum, the Wei River valley experienced a phase of agricultural intensification, which led to a dramatic increase in site numbers and population in this river valley. It then became colder and drier in the late Neolithic and this witnessed a decline in settlement and seemingly a reduction of population. The faunal evidence suggested there was a decrease in animal husbandry and, coincidently, an increase in wild animal hunting for subsistence.

In the early and middle Neolithic, the combinations of plant cultivation and animal herding spurred an increase in population size, and this in turn spurred demographic migrations, with populations moving out from the centres of plant and animal domestication and agricultural origins. The dramatic increase of site

numbers in the Wei River coincided with this. During the late Neolithic, the lesser importance of domestic animals and possibly plant cultivation, resulted in the population moving out from the Wei River into adjacent areas, such the Central plain and the Northern Shaanxi.

In general, the dynamic interactions between environmental changes, subsistence changes and process of social complexity can be concluded as following: with the influence of climate fluctuations throughout the Neolithic, animal subsistence pattern changed accordingly in the Wei River valley, this further spurred social changes in this region.

8.4.5 Assessing methodologies and proposal for future direction

Plant and animal remains have not been given enough attention, and sieving and flotation were seldom undertaken during excavation of most archaeological sites even today since most of them are salvage projects in China. This is also the case for Wayaogou, and most faunal reports only produce species lists; morphometric data were missing or not presented to the same standard. However, this study provides a case study to explore some important zooarchaeological issues with data retrieved without sieving and flotation. This research is mainly based on the analysis of large mammal species, which have much less chance to be biased by the excavation and recovery methods. Various zooarchaeological methods were used in this study and the retrieval bias was assessed and borne in mind all the time.

With limited comparable data from other sites, this research was mainly based on

the faunas from Wayaogou, and the questions and hypotheses it raised need to be confirmed by further case studies in this region. Subsistence studies is a new field for Chinese archaeology, and plant and animal remains have not been given enough attention during the process of excavation and report writing, although the situation has improved considerably in recent decades. Hopefully, the use of questions and hypothesis testing concerning subsistence will spur the improvement of excavation design and technique, and encourage researchers to produce reports with detailed information on plant and animal remains. Archaeological reports with detailed plant and animal information would make comparative studies possible and easier in the future. A few key issues related to the subsistence in this region need to be explored urgently. The most important one is the beginning of pig domestication in this region; and this involves systematic study of faunal remains from sites of the early Neolithic period, such as Dadiwan, which could draw on some of the methodologies successfully used and presented in this thesis. In addition, it would be ideal if we could combine standard zooarchaeological methods, such as morphometrics, cull pattern analyses, and even linear enamel hypoplasia, as has been applied in this thesis, with other approaches, such as stable isotope analysis, mtDNA, geometric morphometrics, and the identification of pens and dung remains. If such combined research could be applied to Dadiwan and other Neolithic sites in this region, we may gain a more thorough understanding of animal usage, and pig domestication and husbandry in particular, in the Wei River valley.

Appendix 4.1: Taxonomic habitat weightings for the large mammal and micro-mammal assemblage from the Wei River valley

Species	forest	forest boarder	Woodland	underbrush	Hillside shrub/grassland	grassland/open meadow	marsh	waterside shrub/reed	bamboo thicket	farm field	scrub desert	mountain
sika deer	0.6					0.2	0.2					
roe deer					0.25		0.5			0.25		
musk deer	0.9							0.1				
red deer	0.2		0.7				0.1					
pere David's deer							0.5	0.5				
cervus unicolor	0.2	0.2			0.2	0.2				0.2		
water deer								0.88		0.12		
Muntiacus reevesi					0.9					0.1		
goral	0.5				0.5							
asiatic elephant	0.4	0.2			0.2	0.2						
Dicerorhinus sumatrensis	0.2	0.2			0.2		0.2	0.2				
Mainland serow (*Capricornis sumatraensis*	0.5											0.5
argali (*Ovis ammon*)												1
mongolian gazelle (*Procacra gutturosa*)						1						
wild boar	0.5							0.3		0.2		

Species	forest	forest boarder	woodland	underbrush	hillside shrub/grassland	grassland/open meadow	marsh	waterside shrub/reed	bamboo thicket	farm field	scrub desert	mountain
monkey (*Rhinopithecus roxellana*)	1											
Macaca mulatta	0.5	0.1			0.2					0.1	0.1	
Badger	0.4		0.4							0.2		
Cat	0.1	0.1	0.1				0.1				0.6	
raccoon dog	0.4	0.3		0.1			0.1	0.1				
Tiger	0.4		0.2		0.2		0.2					
Ursus arctos	0.2	0.2	0.2		0.2						0.2	
Panthera pardus	0.2		0.2		0.2		0.2				0.2	
Felis bengalensis	0.4				0.2	0.1		0.2		0.1		
Cuon alpinus	0.4				0.3			0.3				
raccoon dog	0.4	0.3		0.1			0.1	0.1				
asia black bear	1											
hog badger	0.4				0.2	0.2				0.2		
red fox	0.1	0.2	0.2		0.1	0.1				0.1	0.1	0.1
Beaver	0.6						0.2	0.2				
Weasel	0.6									0.4		
Hare						0.4	0.3			0.3		
water shrew								1				

Species	forest	forest boarder	woodland	underbrush	hillside shrub/grassland	grassland/open meadow	marsh	waterside shrub/reed	bamboo thicket	farm field	scrub desert	mountain
brown rat (*Rattus norvegicus*)						0.5		0.5				
steppe pike (*Ochotona pusilla*)						1						
Giant flying squirrel （*Petaurista petaurista*）	1											
Zokors			0.4			0.4				0.2		
banboo rat	0.3				0.2	0.2			0.3			
tundra vole （*Microtus oeconomus*）						0.5		0.5				
Cricetulus sp.					0.2	0.1		0.2		0.2	0.3	
Hedgehog			0.2		0.2	0.2				0.2	0.2	

Appendix 4.2: Taxa representation of large mammal assemblage from Neolithic sites in the Wei River valley

Site	Deer taxa	Pig	Bos	Caprinae & Antilopae	Other	Total
Guantaoyuan II&III	257	18	13	49	68	405
Dadiwan I	451	156	2	0	92	701
Baijiacun	219	251	116	36	74	696
Jiangzhai I	1136	521	72	0	49	1778
Wayaogou	3440	2338	32	18	194	6022
Dadiwan II	2422	900	43	0	140	3505
Dadiwan III	1581	862	48	0	42	2533
Dadiwan IV	1492	1999	70	0	64	3625
Lingkou III	25	47	0	5	4	81
Quanhucun	399	2011	83	108	45	2646
Kangjia	114	48	51	38	69	320

APPENDIX 5.1: Body part representation of pigs from Wayaogou

Element	Diagnostic zones	MNE	Expected	%
maxilla		79	254	31%
mandible	Anterior	254	254	100%
	Posterior	107	254	42%
atlas		35	177	14%
axis		5	177	2%
scapula	Proximal	93	254	37%
humerus	Proximal	47	254	19%
	Distal	148	254	58%
radius	Proximal	37	254	15%
	Distal	20	254	8%
ulna	Proximal	93	254	37%
	Distal	12	254	5%
metacarpal	Proximal	42	1016	4%
	Distal	13	1016	1%
pelvis	Posterior	55	254	22%
	Anterior	23	254	9%
femur	Proximal	21	254	8%
	Distal	27	254	11%
tibia	Proximal	41	254	16%
	Distal	58	254	23%
metatarsal 2	Proximal	3	254	1%
	Distal	4	254	2%
metatarsal 3	Proximal	13	254	5%
	Distal	6	254	2%
metatarsal 4	Proximal	13	254	5%
	Distal	6	254	2%
metatarsal 5	Proximal	12	254	5%
	Distal	12	254	5%
calcaneum (2)	Proximal	60	254	24%
	Distal	59	254	23%
astragalus (2)		34	254	13%
metatarsal	Proximal	47	1016	5%
	Distal	25	1016	2%
phalanx 1 (16)	Proximal	41	2032	2%
	Shaft	61	2032	3%
	Distal	60	2032	3%
phalanx 2 (16)	Proximal	34	2032	2%
	Shaft	40	2032	2%
	Distal	42	2032	2%
phalanx 3 (16)	Proximal	85	2032	4%
	Distal	86	2032	4%

Appendix 5.2: Measurement data for the length of the lower third molar (M_3) of pigs from archaeological sites across China (only the maximum and minimum and average data are included)

Site	area	dating (B.P.)	no.	max	min	ave
Gongwangling	Northwest China	middle Pleistocene		39	38	38.5
Jinniushan	Northeast China	late phase of middle Pleistocene		45	40	41.7
Zhoukoudian	North China	middle Pleistocene		45	40	41.1
Jiahu	Central plain	9000-7000	12	46.7	36.4	42.3
Cishan	North China	7934-7730	3	45	39.2	41.4
Dadiwan	Northwest China	7800-4800	66	46	30.8	37.1
Banpo	Northwest China	6700-5600				35.8
Wayaogou	Northwest China	7000-6000	18	43.5	33.5	39.1
Beishouling	Northwest China	7000-4500	25	44	32	38
Jiangzhai	Northwest China	6740-3950	19	41.7	30	36.2
Xipo	Northwest China	6900-5000	21	39.7	27.1	34.7
Quanhucun	Central plain	late phase of middle Neolithic	18	44.7	28.4	33.5
shantaisi	Central plain	late Neolithic	14	37.5	29.3	33.2
Wadian	Central plain	late Neolithic	5	37.5	30.4	35.1
Donglongshan	Northwest China	Early Bronze Age	11	37.2	24.7	31.7
Erlitou	Central plain	early Bronze Age	21	36.8	27.3	33.5
Yanshi Shangcheng	Central plain	Bronze Age	468	39.8	23.4	32.7
Fengxi	Northwest China	Bronze Age	5	29.8	26.4	28.2
Yinxu	Central plain	3400 (Bronze Age)				31.4

Notes: A few late Neolithic and Bronze age sites from Central Plain (Shantaisi, Wadian, Erlitou, Yangshi Changcheng and Fengxi) have not been mention in the text and the M_3 measurement data are cited from Luo (2007)

APPENDIX 5.3: Postcranial measurements of pigs from Wayaogou **(**measurement code following von den Driesch 1976)

Scapula					
Context	GLP	SLC			
wy-F1		2.08			
wy-F1		2.12			
wy-H41	3.93				
wy-H41	4.28				
wy-H85	4.00				
wy-H190	3.83	2.57			
H121:12	3.94				
H135:705	3.65				
Humerus					
Context	BT	HT	HTC	BD	BP
wy-H180		2.94	2.00	4.24	
wy-H180		2.86	2.10	4.35	
wy-H41					5.46
wy-H41				4.66	
wy-H85	3.09			3.90	
wy-H190	3.56				
wy-H162	2.88			3.90	
wy-H39	3.05			4.27	
wy-H240	3.75			4.86	
wy-H219	2.95			3.94	
wy-H51	3.20			4.18	
wy-H51	3.10			4.11	
wy-H46	3.50			4.72	
wy-H199	3.60	2.88	2.00		
wy-H199	3.05	3.05	1.95		
wy-H195	3.00	2.69	1.77		
Ulna					
Context	LO	DPA			
Pig					
wy-H152	8.64	4.64			
Radius					
Context	Bp				
wy-T1424F1	2.77				
wy-H180	3.12				
wy-H180	3.07				
wy-H199	3.30				

Tibia					
Context	Bd	Dd			
wy-H199	3.25	3.05			
wy-H199	3.15	2.86			
wy-T1620B(6)	3.38	3.10			
Stragalus					
Context	Bd	Dl	GLl	GLm	
wy-H195:49	2.64	2.22	4.27	3.77	
wy-H170:33	2.54	2.20	4.22	3.67	
wy-H39:60	2.71	2.27	4.39	3.98	
wy-H199:118	2.66	2.35	4.55	4.03	
wy-H199:119	2.39	2.26	4.43	4.03	
wy-H199:120	2.38	2.08	3.97	3.47	
wy-H199:121		2.26	4.26		
wy-H199:116	2.35	2.10	4.25	3.77	
wy-H199:117	2.49	2.12	4.16	3.67	
wy-H96:97	2.38	2.14	4.16	3.74	
Calcaneum					
Context	C+D	GL			
wy-H34:68		8.79			
wy-H199:88	3.04	8.90			

APPENDIX 5.4: Tooth wear stages for pigs at Wayaogou; tooth wear stage recording following Grant (1982)

Context/Sample	C	Dp_4	P_4	M_1	M_2	M_3
wy-F16 2		c				
wy-F3 101			c	n	k	h
wy-F3 102					d	b
wy-F3 104						b
wy-F3 105					e	b
wy-F3 107					b	
wy-H100 25				e	c	
wy-H112 3		d		half erupted-erupting		
wy-H112 5				e	c	
wy-H112 6		c		Half erupted		
wy-H118 13					e	b
wy-H118 14					d	b
wy-H118 15		e		U		
wy-H118 20		U				
wy-H118 5				d	c	a
wy-H118 6					d	b
wy-H118 7					d	b
wy-H122 1					d	
wy-H124 12					d	a
wy-H124 22		e		d		
wy-H124 5			e	f	e	d

Context	C	Dp_4	P_4	M_1	M_2	M_3
wy-H124 6					e	b
wy-H124 7	a	d		b		
wy-H124 8						e
wy-H1322(4) 6				d	U	
wy-H1322(4) 7		c		b		
wy-H1322(4) 8		d		c		
wy-H1322(4) 9					d	half erupted
wy-H135 45			e	h	e	c
wy-H135 46	a	d				
wy-H135 51					d	
wy-H135 52						crypt
wy-H135 53		a				
wy-H135 54		b				
wy-H139 33				e	b	U
wy-H139				e	c	
wy-H139 36						half erupted
wy-H14 1					a	
wy-H142 45					g /f	d
wy-H142 46				d	c	half erupted
wy-H146 62		d		b		
wy-H148 28					d	half erupted
wy-H148 30					half erupted	
wy-H148 31		d		half erupted		
wy-H148 33		d		half erupted		

Context/Sample	C	Dp_4	P_4	M_1	M_2	M_3
wy-H15 1				e	c	
wy-H148 34		d		half erupted		
wy-H148 35		d				
wy-H150 140				n	j	h
wy-H150 142						c
wy-H150 143		d		a		
wy-H150 144				e	e /d	half erupted
wy-H150 146		d		half erupted		
wy-H150 147				e	c	erupting through bone
wy-H150 153		d		b		
wy-H150 156		b		half erupted		
wy-H150 158		c				
wy-H150 167				c		
wy-H152 46		d		b		
wy-H154 82			d	e	d	c
wy-H154 84				d	b/a	
wy-H155 2		a				
wy-H155 3		c				
wy-H155 4		d		a		
wy-H156 103			e	n	k	d
wy-H156 104			e	g	d	c
wy-H156 84					e	b
wy-H156 85					e	b
wy-H156 87				d	U	

Context/Sample	C	Dp_4	P_4	M_1	M_2	M_3
wy-H160 2		c				
wy-H156 90					c	
wy-H158 1		f		d	b/a	
wy-H162 42					d	b
wy-H162 50					b	
wy-H162 51		d				
wy-H164 26		d		a		
wy-H167 25			d	e	d	c
wy-H167 27					c	
wy-H169 2				e	b/c	
wy-H170						half erupted
wy-H177 4		broken		half erupted		
wy-h179 17					c	
wy-H179 19		c		erupting through bone		
wy-h179 21				half erupted		
wy-H180 20		e		d		
wy-H180 34					c /d	b
wy-H180 38					f	d
wy-H180 40					c /d	b
wy-H180 41				d	c	
wy-H180 42					c	
wy-H180 43				e	d	half erupted
wy-H180 44					e	b

Context/Sample	C	Dp_4	P_4	M_1	M_2	M_3
wy-H182 3					j	h
wy-H180 48				e	d	
wy-H180 54				d		
wy-H181 4			d			
wy-H185 24		b		half erupted		
wy-H190 21				h	e	
wy-H190 22				e	d	
wy-H190 23		g		d		
wy-H190 38			e	k		
wy-H193 38				d	c	
wy-H193 39				f		
wy-H193 41				d	b	
wy-H195 10					f	c
wy-H195 11				f	b	half erupted
wy-H195 12	a	a				
wy-H195 13		e				
wy-H195 14	a	e		d		
wy-H195 9						d
wy-H197 10		d		c		
wy-H197 5			e	e		
wy-H197 8			c	d /e	d	b
wy-H197 9			b			
wy-H199 527				b		

Context/Sample	C	Dp_4	P_4	M_1	M_2	M_3
wy-H199 536		d		b		
wy-H199 528		g		d	half erupted	
wy-H199 529						crypt
wy-H199 532		b				
wy-H199 533		f		c		
wy-H210		b				
wy-H210 2		d		a		
wy-H211 1			e	g	f	c
wy-H211 3						d
wy-H216 1				f	e	b
wy-H216 2		a				
wy-H216 2		d		a		
wy-H216 3		c		b		
wy-H218 1		c		a		
wy-H219 74				f	e	c
wy-H219 75		d		b		
wy-H219 75		d		a		
wy-H225 58		f		d		
wy-H227 19				e	d	
wy-H227 20					e	c /b
wy-H227 21				f	e	c
wy-H227 24		d		c		
wy-H228 1				e	d	c

Context/Sample	C	Dp_4	P_4	M_1	M_2	M_3
wy-H240 39						d
wy-H228 3						half erupted
wy-H228 6				d		
wy-H235 32				f	d	c
wy-H235 33		c				
wy-H240 35				d	c	
wy-H240 36		e		c		
wy-H240 41		f		d	u	
wy-H38 3					d	c
wy-H39 68		half erupted				
wy-H41 12		a				
wy-H41 8					d	half erupted
wy-H45 7				e	c	
wy-H45 8				d	c	
wy-H46 28		c				
wy-H46 29		c		b		
wy-H51 8		e		c		
wy-H51 9					e	b
wy-H64 6				e	d	b
wy-H64 7		e		d		
wy-H85 12		a				
wy-H85 4		d		c		
wy-H85 5				b		

Context/Sample	C	Dp_4	P_4	M_1	M_2	M_3
wy-T1321(5) 3		d		c		
wy-H85 9		a				
wy-H96 12						d
wy-H96 14		e		d	U	
wy-H96 19	p	f		d		
wy-H96 20				d	half erupted	
wy-H96 21	p	e		d		
wy-H96 24		b		a		
wy-T1322(4) 7		b				
wy-T1323(4) 1			d	e	d	half erupted
wy-T1323H68 B6				e	d	half erupted
Wy-T1424F1 100			broken	d	b/a	
Wy-T1424F1 105		d				
Wy-T1424F1 99	m		e	l	f	
Wy-T1424F1 F1		a				
wy-T1425(2) 7		a				
Wy-T1726(3) 20						d
wy-T1726(3) 3		a				
wy-T1726(3) 4		b				
Wy-T2022(2) 11		e		c	half erupted	crypt
Wy-T2022(2) 12				f	d	half erupted

APPENDIX 5.5: Linear enamel hypoplasia recording for pigs from Wayaogou
(Code: comp.=completed; sev.=severity; ab.=absent; dep.=depression; brok.=broken)

Context	M_1							M_2								M_3									
	Hypoplasia							Hypoplasia								Hypoplasia									
	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	Crown comp.?	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	M cusp	crown height	P cusp	crown height	type	Sev.
H118:6	ab.							no	d	1.93		none		dep.	1	yes	c	3.58	16.01	3.59	15.26			line	3
H195:10	ab.							no	f	none		none				no	d	3.31		4.15		3.18		dep., shift	3
H197:8	f	none		none				no	d	none		2.50		dep.	1	no	c	none		none		none			
H195:9	ab.							no	f	none		none				no	d	3.29		3.87				dep. and shift	3
H152:46	c	6.01	11.01	3.41	9.05	dep.	2	no	C																
H38:3	ab.							no	d							yes	c	1.77	14.86	1.83				line	3
H180:44								no	f	none							d	5.12						dep.	1
H190:22		none		none				no	d	none		none					ab.								
H124:6	ab.							no	e	none						yes	c	none		none		none			
H211:1	g	none						no	e	2.03		none			1	yes	c	2.37		none		none		line	1
H240:39	ab.								ab.							no	d								
H150:153	c	4.04	10.74	none		dep.	1	no	ab.																
H124:12	ab.								d	none		3.07		Dep	1	yes	b	1.76	14.35					line	3
H156:104	g	none						no	e	none		none				yes	c	1.98	13.28	2.98	13.41	none		line	2

`Context	M_1							M_2								M_3									
	Hypoplasia							Hypoplasia								Hypoplasia									
	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	M cusp	crown height	P cusp	crown height	type	Sev.
H135:45	j							no	e	3.41		3.42		dep.		no	d	2.87		2.88		none		dep.	2
H135:57	j							no	e			3.08		dep.	3	no	d	2.88				none		dep.	1
H156:103	n							no	k	none		none				no	d	none		none		none			
H124:11	c	none		none					c																
H124:7	c	none		none					c																
H124:8	ab.								ab.							no		2.08		none		none		line	
H180:45	ab.								ab.								c	3.63	15.63	none		none		dep.	1
H190:23	d	none		none					ab.																
H180:34									d	none		2.52		dep.	2		c			none					
H180:38	ab.								g								d	none		brok.		none			
T1621H96:12	ab.							no	j							no	d			none		none			
H96:20	d	none		none					u																
H180:40	ab.								ab.							yes	c	2.40		2.37				dep.	3
H180:40																				7.17				dep.	1
H199:528	d			3.00	dep.		2		u																
H180:41	d	none		none				yes	c			2.54	12.12	line	2		ab.								

Context	M_1							M_2								M_3									
	Hypoplasia							Hypoplasia								Hypoplasia									
	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	M cusp	crown height	P cusp	crown height	type	Sev.
H156:84	ab.							no	f	3.75		2.21		dep.	3		c	3.79	13.85	3.06	12.73	none		dep.	1
H180:39	d	none		none				yes	c	none		none													
H142:45	ab.							no	g	none		none				no	f								
H180:48	f	none		none				no	e	none		3.87		dep.	2		ab.								
H51:9	ab.								f	1.65		none			2							brok.			
H240:35	e	none		none				no	d	4.60		3.22		dep.	2										
H240:36	c	none		none					ab.																
H118:7	ab.							no	d	3.15		2.68		dep.	1		c	2.75	14.84	2.38	13.70	none		dep.	2
H118:14	ab.							no	d	none		none					c	3.17	14.31	2.67	13.73	none		dep.	1
H118:13	ab.							no	d	4.16		3.26		line	3		d	none		6.24		3.31			
H240:41	d	none		none				yes	a	none		none					ab.								
T2022(2):11	d	2.35		none			1		E																
H51:8	c	none	8.96	none	8.67																				
H150:41	g	none		none				no	d	broken		3.16		dep.	1		c	3.54	14.15	none	13.91	none		dep.	
H64:6	e	none		none				no	d	none							ab.								
H64:6	e							no	d	none		none				broken	c								

context	M_1							M_2								M_3									
	Hypoplasia							Hypoplasia								Hypoplasia									
	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	M cusp	crown height	P cusp	crown height	type	Sev.
H124:22	d	4.69		none					ab.								ab.								
H193:38	d	none		none				yes	c	none	12.5														
H139:35	f								d			none													
H180:46	c	6.18		brok.			1																		
H180:42	d	none		3.23			2		b	none		none					ab.								
H156:85	ab.											none					d	1.83						dep.	2
H156:87	d	none		none					a	none															
H180:55	ab.								ab.								b	none		none					
H17:39	d	none		none					c									5.88							2
H124:5	g	none		none					e								d								
H195:11	d	none		none					E																
H124:21	d	none		none													ab.								
H199:533	d	none		3.06			1										ab.								
H154:84	e	none		none					a																
H150:142	ab.								ab.								d			2.32		none		dep.	1
H190:21	j	none		none					g	none		3.00		dep.	2		ab.								

context	M_1							M_2								M_3									
	Hypoplasia							Hypoplasia								Hypoplasia									
	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	P cusp	crown height	type	Sev.	crown comp.?	TWS	A cusp	crown height	M cusp	crown height	P cusp	crown height	type	Sev.
T2022(2):12	g	none		none					d	4.84		2.84		dep.	2		E	none							
H199:527	c	5.70	10.25	2.45	8.94	dep.	2		ab.								ab.								
H199:536	c	none		none					ab.																
H227:21	f	none		none					f			none					c			6.47					
H227:24	c	1.32	10.00	none	8.95	dep.	1		V																
H227:20	ab.								g	none		none					d	3.54						dep.	1
H96:19	e	none		none																					
H227:19	f								e	none		none													
H228:1	f	none		none					e			none					d	6.14		4.6				dep.	2

Appendix 6.1: Body part representation of sika deer from Wayaogou

Diagnostic zones	MNE	Expected	%
Antler	104	200	52%
Maxilla	42	200	21%
A Mandible	200	200	100.00%
P Mandible	49	200	24.50%
Atlas	5	100	5.00%
Axis	11	100	11.00%
P Humerus	17	200	8.50%
D Humerus	137	200	68.50%
P Scapular	102	200	51.00%
P Radius	95	200	47.50%
D Radius	71	200	35.50%
P Ulna	74	200	37.00%
P Pelvis	79	200	39.50%
A Pelvis	35	200	17.50%
P Femur	52	200	26.00%
D Femur	56	200	28.00%
P Tibia	36	200	18.00%
D Tibia	98	200	49.00%
P Metacarpal	109	200	54.50%
D Metacarpal	34	200	17.00%
P Metatarsal	142	200	71.00%
D Metatarsal	56	200	28.00%
P Calcaneum	167	200	83.50%
D Calcaneum	162	200	81.00%
Astragalus	154	200	77.00%
P Phalanx 1	158	800	19.75%
D Phalanx 1	159	800	19.88%
P Phalanx 2	78	800	9.75%
D Phalanx 2	88	800	11.00%
P Phalanx 3	62	800	7.75%
D Phalanx 3	63	800	7.88%

Appendix 6.2: Sika deer postcranial measurement at Wayaogou **(**measurement code following von den Driesch 1976)

scapula	GLP	SLC		
	4.38	2.20		
	5.20			
	5.20			
	4.49			
	4.49			
	4.77			
	4.37	2.53		
	4.17	2.32		
	4.97			
	4.18	2.27		
	4.62			
	5.06	2.75		
	5.10	3.01		
	4.65			
	5.15			
	4.76			
	3.76	2.80		
	4.86			
	5.33	3.08		
	4.32			
	4.56	2.70		
	4.74	2.54		
	4.50			
	5.08			
	4.48			
	5.06			
	4.53			
	4.52			
	4.42			
	4.63			
	4.70			
	4.47			
	4.49			
	4.64	2.17		
	5.02	2.95		
	4.82	2.70		

Humerus	BT	HT	Bd	
	4.07	3.22	4.62	
	4.38			
	4.30	3.11	4.68	
	3.95	3.20	4.40	
	4.21	3.40		
	4.00		4.68	
	4.60	3.28		
	4.30	3.19		
	4.17	3.20		
	3.93	3.22		
	3.77	2.79		
	4.03	3.14		
	4.32	3.30		
	4.12	3.03		
	4.10	3.12		
	3.90	3.32		
	3.69	3.02		
		3.06		
	3.67	2.91		
	3.92	3.11		
	4.04	3.13		
	3.97	3.10		
	4.20		4.88	
	4.26	3.48		
	4.07	3.10		
	4.19			
	4.10	3.32		
	4.04	3.13		
	3.97	3.16		
	4.08	3.10		
Radius	**Bp**	**BFp**	**Bd**	
wy-H180	4.81	4.32		
wy-H180	4.26	4.74		
wy-H180	4.37	3.86		
wy-H180	4.76			
wy-H118	4.35			
wy-H118			4.21	
wy-H190	4.43	3.94		
wy-H190	4.40	3.84		

Radius	Bp	BFp	Bd	
wy-H190	4.16	3.72		
wy-H190	4.70	4.35		
wy-H190	4.62	4.25		
wy-H190			3.68	
wy-H190	3.71			
wy-H190			3.87	
wy-H199	4.58	4.12		
wy-H199	4.40	3.94		
wy-H199			4.27	
wy-H199			4.35	
wy-H199			3.93	
Tibia	**Bd**	**Dd**		
wy-T1424F1	3.80	2.72		
wy-H190	4.30	3.13		
wy-H190	3.98	2.75		
wy-H190	4.30	3.11		
wy-H199	4.18	3.26		
wy-H199	4.05	2.91		
wy-H199	4.04	3.16		
wy-H199	4.13	3.37		
wy-H199	4.27	3.29		
wy-H199	4.09	3.16		
wy-H199	3.61	2.94		
Calc.	**C**	**C+D**	**GL**	
wy-H227 82			10.10	
wy-H228 49	1.84	3.64	10.50	
wy-H228 48	1.83	3.44	8.46	
wy-H180 121	1.85	3.60	9.68	
wy-T1424F1			6.70	
wy-H34 65			9.74	
wy-H34 63			9.95	
wy-H34 64			9.85	
wy-H190 132			10.40	
wy-H190 132	1.93	3.70		
wy-H190 133				
wy-H190	2.87	3.63	10.30	
wy-H199 83	1.77	3.22	9.39	

Tibia	Bd	Dd		
wy-H199 99			9.53	
wy-H199 82			9.6	
astragalus	**Bd**	**Dl**	**GLl**	**GLm**
wy-H195	2.65	2.35	4.46	4.03
wy-H195	2.95	2.57	4.86	4.52
wy-H152	2.93	2.52	4.58	4.36
wy-H152	2.72	2.42	4.39	4.22
wy-H227	2.88	2.55	4.8	4.40
wy-H227	2.68	2.34	4.39	4.00
wy-H228	2.84	2.65	4.97	4.42
wy-H228	2.71	2.47	4.63	4.27
wy-H228	2.64	2.28	4.45	4.14
wy-H228	2.76	2.45	4.62	4.27
wy-H228	2.55	2.26	4.35	4.07
wy-H180	2.48	2.28	4.35	4.01
wy-H180	2.75	2.46	4.59	4.27
wy-H180	2.58	2.28	4.18	3.79
wy-H180	2.53	2.43	4.39	4.08
wy-T1424F1	2.48	2.24	4.30	3.97
wy-H154	2.74	2.44	4.54	4.17
wy-H154	2.84	2.65	4.73	4.64
wy-H154	2.93	2.59	4.88	4.50
wy-H170	2.82	2.54	4.56	4.22
wy-H170	2.61	2.4	4.56	4.19
wy-H118	2.81	2.54	4.54	4.11
wy-H179	2.41	2.12	4.16	3.86
wy-H179	2.99	2.53	4.89	4.46
wy-H190	2.65	2.39	4.59	4.22
wy-H190	3.04	2.62	4.93	4.55
wy-H190	2.85	2.44	4.40	4.03
wy-H190	2.64	2.33	4.36	4.04
wy-H190	2.68	2.32	4.35	4.05
wy-H190	2.51	2.23	4.30	4.05
wy-H34	2.90	2.55	4.77	4.37
wy-H185	3.00	2.41	4.47	4.19
wy-H72	2.98	2.69	4.94	4.44
wy-H189	3.00	2.67	4.77	4.41
wy-H199	2.83	2.58	4.63	4.1
wy-H199	2.70	2.42	4.67	4.29
wy-H199	2.63	2.36	4.32	
wy-H199	2.90	2.34	4.41	4.05

astragalus	Bd	Dl	GLl	GLm
wy-H199		2.47		4.31
wy-H199	2.56	2.35	4.14	3.96
wy-H199	2.87	2.56	4.69	4.39
wy-H199	2.78	2.33	4.43	4.09
wy-H199	2.86	2.55	4.80	4.51
wy-H96	2.60	2.42	4.53	4.20
wy-H229	3.19	27.40	4.88	4.54
wy-H229	2.80	2.48	4.67	4.27
wy-H229	2.30	2.54	4.68	4.44

Appendix 6.3: Tooth wear stages for sika deer from Wayaogou
(wear score recording following Brown and Chapman 1990; 1991)

sample No.	Premolar wear scores	Molar wear scores		
	P_4	M_1	M_2	M_3
1	11	35	34	40
2	8	32	27	26
3	10	broken	31	26
4	12	35	34	29
5	5	27	25	24
6	10	35	32	32
7	missing	34	29	25
8	10	34	30	27
9	not erupted, dp_4 is present	27	16	missing
10	not erupted, dp_4 worn	25		
11	missing	30	26	30
12	broken	32	missing	missing
13	9	34	missing	
14	not erupted, dp_4 is present	23	fully erupted	not present
15	not present, dp_4 is worn	25	in crupt	
16	not erupt, dp_4 is slightly worn	in crupt, the distal cusp is missing		
17	not erupted, dp_4 is worn	25	6	
18	10	34	missing	36
19	10	30	27	missing
20	missing	missing	36	43
21	10	32	32	
22	not present, dp_4 is heavily	28	20	
23	not present, dp_4 is worn	25		
24	missing	missing	missing	broken
25	missing	25	18	half erupted
26	5	broken	broken	broken
27	11	35	34	missing
28	10	34	32	
29	12	36	34	41
30	11	33	31	
31	dp_4 is present, p_4 not erupted	25	broken	
32	10	34	32	missing
33		28	dark dentition	dark dentition
34			35	41

sample No.	Premolar wear scores	Molar wear scores		
	P_4	M_1	M_2	M_3
35	missing	missing	missing	27
36	missing	missing	28	26
37		missing	34	37
38	broken	29	24	broken
39	missing	missing	26	3
40	missing	broken	30	29
41	10	34	missing	missing
42	11	34	32	missing
43	missing	34	31	missing
44	missing	missing	missing	14
45	dp_4 is heavily worn; p_4 is not present	29?	25?	half erupted
46	11	missing	missing	missing
47	missing	missing	missing	25
48	10	34	broken	
49	dp_4 is present and slightly worn, p4 has not erupted			
50	dp_4 is present and moderate	worn		
51	1	missing	missing	
52	dp_4 is moderate worn			
53	dp_4 is slightly worn			
54	2	34	29	25
55	dp_4 is heavily worn	30	17	
56	2	27	27	
57	missing	35	missing	missing
58	dp_4 is moderate worn	26	half erupted	
59	12	43	36	broken,heavy
60	9	24	21	16
61	13	36	broken	missing
62	9			
63	dp_4 is moderate worn	24	missing	missing
64	dp_4 is slightly worn	6		
65	5	32	27	23
66	missing	missing	broken	26
67	missing	missing	missing	36
68		broken	broken	1
69	missing	missing	missing	25

sample No.	Premolar wear scores	Molar wear scores		
	P_4	M_1	M_2	M_3
70	9			
71	dp_4 is moderate worn	25		
72	12			
73				23
74				23
75		34	34	
76				36
77	10	34		
78	dp_4 is moderate worn, p_4 is not present	24		
79		34	32	33
80			19	
81	10	30		
82	3	30	27	
83			35	
84	10			
85		32	32	
86	10	30		
87		31	24	3
88			40	
89	11	35		
90	12	36	34	40
91	12	36	34	40

Note: the molar wear scores recording following Brown and Chapman (1990, 1991), each location on the premolars and molars is scored separately and then added up to archive the score for each teeth.

APPENDIX 7.1 Bone densities (NISP/m^3) of each ash pit

grid	feature	size						NISP	NISP per m^3
		diameter				depth (cm)	V(m^3)		
		mouth		bottom					
		min. (cm)	max. (cm)	min. (cm)	max. (cm)				
T1322	wy-H1	185.0	225.0	160.0	175.0	48.0	5.2	13.0	2.5
T1523	wy-H100	135.0	140.0	110.0	164.0	69.0	4.0	38.0	9.5
T1322	wy-H101	216.0	216.0	216.0	216.0	70.0	10.3	2.0	0.2
T1527	wy-H102	210.0	210.0	202.0	202.0	46.0	6.1	8.0	1.3
T1322	wy-H103	164.0	164.0	105.0	105.0	60.0	3.5	2.0	0.6
T1322	wy-H106	170.0	180.0	110.0	150.0	105.0	7.6	2.0	0.3
T1322	wy-H109	82.0	153.0	60.0	153.0	48.0	1.6	2.0	1.2
T1322	wy-H112	405.0	405.0	405.0	405.0	275.0	141.7	14.0	0.1
T1320	wy-H113	105.0	280.0	105.0	280.0	126.0	11.6	5.0	0.4
T1826	wy-H114	200.0	200.0	198.0	198.0	70.0	8.7	7.0	0.8
T1320	wy-H116	160.0	160.0	136.0	136.0	70.0	4.8	1.0	0.2
T1725	wy-H118						6.9	136.0	19.7
T1428	wy-H121	180.0	180.0	120.0	200.0	70.0	6.2	75.0	12.1
T1428	wy-H122	220.0	250.0	134.0	280.0	210.0	30.3	10.0	0.3
T2128	wy-H124	100.0	470.0	80.0	160.0	200.0	17.7	42.0	2.4
T1427	wy-H125	104.0	120.0	170.0	326.0	194.0	19.1	3.0	0.2
T1422	wy-H13	115.0	115.0	155.0	155.0	54.0	3.1	37.0	11.9
T1628	wy-H135	160.0	160.0	170.0	170.0	210.0	18.0	169.0	9.4
T1428	wy-H137	232.0	232.0	210.0	210.0	236.0	36.2	9.0	0.2
T1629	wy-H138	92.0	92.0	60.0	60.0	56.0	1.0	1.0	1.0
T1629	wy-H139	150.0	150.0	208.0	208.0	170.0	17.3	52.0	3.0
T1321	wy-H14	130.0	130.0	30.0	30.0	50.0	1.1	1.0	0.9
T1629	wy-H140	120.0	170.0	120.0	94.0	94.0	4.6	24.0	5.2
T1428	wy-H142	150.0	150.0	108.0	168.0	70.0	4.5	55.0	12.3
T1725	wy-H143	150.0	150.0	148.0	148.0	20.0	1.4	15.0	10.8
T1629	wy-H144	140.0	140.0	120.0	120.0	136.0	7.2	28.0	3.9
T2026	wy-H145	210.0	234.0	210.0	234.0	110.0	17.0	17.0	1.0
T1926	wy-H146	220.0	290.0	130.0	140.0	170.0	20.7	18.0	0.9
T1629	wy-H148	145.0	145.0	164.0	164.0	130.0	9.8	35.0	3.6
T2026	wy-H151	150.0	200.0	150.0	200.0	100.0	9.4	23.0	2.4
T2026	wy-H152	128.0	166.0	212.0	510.0	174.0	32.3	98.0	3.0
T2026	wy-H154	110.0	140.0	126.0	240.0	200.0	14.1	82.0	5.8
T1926	wy-H155	200.0	250.0	180.0	210.0	120.0	16.5	22.0	1.3
T1925	wy-H156						53.2	89.0	1.7
T1626	wy-H158	148.0	296.0	128.0	285.0	48.0	6.0	2.0	0.3

grid	feature	size						NISP	NISP per m^3
		diameter				depth (cm)	V(m^3)		
		mouth		bottom					
		min. (cm)	max. (cm)	min. (cm)	max. (cm)				
T1726	wy-H161		310-176	310-70		240.0	9.2	21.0	2.3
T1727	wy-H161		365-165	80-40		260.0	9.5	21.0	2.2
T1827	wy-H161						30.4	42.0	1.4
T1927	wy-H161						4.5	18.0	4.0
T2425	wy-H162	230.0	900.0	230.0	900.0	190.0	123.6	54.0	0.4
T1825	wy-H163	144.0	144.0	144.0	144.0	38.0	2.5	4.0	1.6
T2126	wy-H164	234.0	234.0	50.0	60.0	176.0	13.0	34.0	2.6
T1825	wy-H165	60.0	210.0	60.0	190.0	20.0	0.8	1.0	1.3
T2126	wy-H166	140.0	210.0	160.0	160.0	104.0	9.0	12.0	1.3
T2126	wy-H167	170.0	194.0	50.0	110.0	160.0	8.7	29.0	3.3
T1925	wy-H169	102.0	102.0	72.0	108.0	166.0	4.7	18.0	3.8
T1423	wy-H17	205.0	295.0	175.0	234.0	90.0	14.2	50.0	3.5
T1927	wy-H170	240.0	240.0	290.0	290.0	146.0	32.3	166.0	5.1
T1922	wy-H173	202.0	220.0	200.0	230.0	134.0	19.0	15.0	0.8
T1922	wy-H174	152.0	218.0	150.0	180.0	150.0	14.1	6.0	0.4
T2025	wy-H176	110.0	110.0	46.0	110.0	80.0	2.1	31.0	14.8
T1726	wy-H177	180.0	200.0	150.0	165.0	60.0	5.7	27.0	4.7
T2025	wy-H179	110.0	110.0	90.0	150.0	93.0	3.7	102.0	27.3
T1631	wy-H181	200.0	210.0	180.0	200.0	50.0	6.1	9.0	1.5
T2024	wy-H182	160.0	190.0	120.0	120.0	144.0	9.9	27.0	2.7
T1530	wy-H184	210.0	280.0	210.0	280.0	90.0	16.6	1.0	0.1
T1530	wy-H185	140.0	140.0	136.0	200.0	160.0	11.7	27.0	2.3
T2024	wy-H186	86.0	150.0	114.0	130.0	134.0	5.8	18.0	3.1
T1631	wy-H189	186.0	200.0	186.0	200.0	50.0	5.8	41.0	7.0
T1822	wy-H190	326.0	560.0	200.0	500.0	132.0	57.7	168.0	2.9
T1724	wy-H192	200.0	200.0	150.0	150.0	115.0	11.1	9.0	0.8
T1823	wy-H193	208.0	208.0	110.0	110.0	146.0	12.0	40.0	3.3
T2023	wy-H195	340.0	400.0	400.0	400.0	150.0	69.7	63.0	0.9
T1923	wy-H196	450.0	450.0	450.0	450.0	110.0	70.0	7.0	0.1
T1923	wy-H197	170.0	170.0	142.0	330.0	210.0	24.8	57.0	2.3
	wy-H199	90.0	90.0	86.0	160.0	136.0	4.6	251.0	54.4
T1423	wy-H20	150.0	150.0	148.0	148.0	7.0	0.5	3.0	6.1
T2028	wy-H200	215.0	400.0	224.0	356.0	110.0	28.6	26.0	0.9
T2229	wy-H203	120.0	120.0	120.0	120.0	40.0	1.8	5.0	2.8
T2228	wy-H210	128.0	228.0	178.0	178.0	138.0	13.2	25.0	1.9
T2229	wy-H211	234.0	234.0	72.0	72.0	106.0	8.5	8.0	0.9
T2228	wy-H212	164.0	174.0	100.0	100.0	136.0	7.9	21.0	2.7

grid	feature	size						NISP	NISP per m^3
		diameter				depth (cm)	V(m^3)		
		mouth		bottom					
		min. (cm)	max. (cm)	min. (cm)	max. (cm)				
T1625	wy-H218	160.0	160.0	102.0	102.0	148.0	8.1	7.0	0.9
T1924	wy-H219	100.0	150.0	110.0	160.0	89.0	4.6	127.0	27.9
T1726	wy-H222	70.0	130.0	70.0	130.0	70.0	2.0	1.0	0.5
T2126	wy-H224	116.0	116.0	72.0	72.0	152.0	4.3	9.0	2.1
T1824	wy-H225	370.0	370.0	360.0	360.0	95.0	39.8	57.0	1.4
T1919	wy-H227	220.0	220.0	100.0	100.0	200.0	16.8	43.0	2.6
T1924	wy-H228	130.0	145.0	80.0	170.0	105.0	5.3	86.0	16.1
T2123	wy-H229	210.0	310.0	150.0	260.0	150.0	24.3	26.0	1.1
T1824	wy-H231	110.0	110.0	105.0	105.0	55.0	2.0	3.0	1.5
T2123	wy-H233	180.0	192.0	160.0	182.0	80.0	8.0	8.0	1.0
T2021	wy-H235	296.0	296.0	51.0	92.0	240.0	28.3	32.0	1.1
T2020	wy-H236	144.0	218.0	95.0	180.0	40.0	3.0	1.0	0.3
T1921	wy-H238	138.0	138.0	126.0	126.0	78.0	4.3	26.0	6.1
T1821	wy-H239	138.0	138.0	50.0	50.0	110.0	3.3	8.0	2.4
T2021	wy-H240	156.0	320.0	156.0	320.0	60.0	9.4	42.0	4.5
T1423	wy-H28	118.0	148.0	90.0	108.0	40.0	1.7	15.0	8.9
T1421	wy-H29	135.0	135.0	141.0	141.0	32.0	1.9	40.0	20.9
T1320	wy-H3	215.0	400.0	224.0	356.0	110.0	28.6	5.0	0.2
T1424	wy-H4	98.0	98.0	94.0	94.0	50.0	1.4	24.0	16.6
T1320	wy-H40	90.0	310.0	70.0	280.0	80.0	5.9	14.0	2.4
T1421	wy-H41	125.0	130.0	180.0	182.0	114.0	8.6	71.0	8.3
T1323	wy-H42	92.0	126.0	90.0	126.0	90.0	3.2	1.0	0.3
T1323	wy-H43	130.0	130.0	100.0	100.0	28.0	1.2	1.0	0.9
T1321	wy-H44	200.0	200.0	190.0	190.0	60.0	7.2	2.0	0.3
T1323	wy-H45	150.0	150.0	154.0	154.0	64.0	4.6	16.0	3.4
T1525	wy-H46	180.0	160.0	86.0	86.0	112.0	6.0	28.0	4.7
T1525	wy-H47	180.0	210.0	114.0	160.0	160.0	13.8	7.0	0.5
T1326	wy-H48	110.0	172.0	126.0	166.0	67.0	4.2	22.0	5.2
T1525	wy-H49	84.0	154.0	150.0	150.0	122.0	6.7	4.0	0.6
T1422	wy-H5	160.0	220.0	135.0	202.0	47.5	4.6	18.0	3.9
T1621	wy-H51	60.0	60.0	175.0	175.0	180.0	8.4	16.0	1.9
T1622	wy-H52	164.0	180.0	20.0	20.0	84.0	2.9	24.0	8.2
T1722	wy-H54	175.0	175.0	175.0	175.0	90.0	8.7	5.0	0.6
T1720	wy-H55	132.0	132.0	152.0	152.0	122.0	7.7	15.0	1.9
T1420	wy-H6	130.0	130.0	80.0	80.0	50.0	1.8	3.0	1.7
T1620	wy-H63	158.0	158.0	65.0	65.0	66.0	2.7	1.0	0.4
T1621	wy-H64	110.0	110.0	166.0	166.0	194.0	11.8	27.0	2.3
T1323	wy-H65	70.0	166.0	70.0	120.0	50.0	1.6	4.0	2.6

grid	feature	size						NISP	NISP per m^3
		diameter				depth (cm)	V(m^3)		
		mouth		bottom					
		min. (cm)	max. (cm)	min. (cm)	max. (cm)				
T1720	wy-H66	106.0	106.0	40.0	40.0	45.0	0.8	1.0	1.2
T1720	wy-H67	112.0	112.0	132.0	132.0	118.0	5.5	23.0	4.2
T1323	wy-H68	90.0	130.0	80.0	80.0	64.0	1.8	49.0	27.3
T1620	wy-H72	200.0	250.0	160.0	220.0	110.0	14.6	21.0	1.4
T1622	wy-H75	150.0	150.0	150.0	150.0	50.0	3.5	13.0	3.7
T1420	wy-H8	90.0	90.0	93.0	93.0	35.0	0.9	2.0	2.2
T1720	wy-H84	110.0	110.0	142.0	142.0	76.0	3.8	8.0	2.1
T1621	wy-H85	112.0	112.0	220.0	220.0	150.0	13.4	78.0	5.8
T1621	wy-H88	130.0	130.0	210.0	210.0	118.0	10.9	38.0	3.5
T1523	wy-H94	90.0	90.0	78.0	105.0	66.0	1.7	18.0	10.7
T1621	wy-H96	110.0	140.0	240.0	350.0	150.0	21.3	89.0	4.2
T1321	wy-H97	126.0	126.0	92.0	92.0	82.0	3.1	7.0	2.3
T1523	wy-H98	172.0	172.0	100.0	100.0	84.0	5.0	1.0	0.2
T1926	wy-H159	140.0	160.0	180.0	194.0	140.0	12.5	18.0	1.4
T1824	wy-H216	100.0	100.0	175.0	220.0	100.0	7.1	55.0	7.7

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